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PATENT
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HIV VACCINE CANDIDATE PEPTIDES

CLAIM OF PRIORITY

This application claims priority under 35 U.S.C. § 119(e) to United States provisional patent applications 60/092,346, filed July 10, 1998; 60/115,145, filed January 8, 1999; and 60/130,677, filed April 23, 1999.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

This invention was made with United States Government support from the National Institutes of Health. The Government may have certain rights in the invention.

TECHNICAL FIELD OF THE INVENTION

This invention relates generally to vaccines, particularly to vaccines to human immunodeficiency virus 1 (HIV-1).

BACKGROUND OF THE INVENTION

The need for an effective vaccine against human immunodeficiency virus type 1 (HIV-1), one that takes into consideration the variability of HIV strains, remains urgent. Researchers have yet to achieve the development of an HIV vaccine that will stimulate effective immune responses to most of the many different strains ("clades") of HIV now being transmitted in course of the global HIV epidemic. At the root of the problem is the great diversity of HIV itself, and the restriction of human cytotoxic T cell (CTL) response to variant strains of HIV.

In the course of developing HIV vaccines, most researchers have focused on defining immune responses against a particular vaccine candidate. Most of these candidate

vaccines in Phase I through Phase III trials at present belong to the group of clade B strains of HIV. Some of these vaccine candidates are derived from lab strains of HIV, others are derived from clade B patient isolates. "Challenge" strains of HIV, to which immunized individuals may be exposed, may be 10 to 15% different at the level of their sequences. Challenge strains in other regions of the world, and new strains arriving in the US from other regions of the world may be even more dramatically divergent. These variations may allow the challenge strains to elude the vaccine-mediated CTL responses. In other words, due to strain variations, immune responses raised against one vaccine strain may not protect against other strains of HIV.

The root of this problem is the interaction between viral protein sequences and the molecules of the immune system (the human leukocyte antigens; HLA), whose duty it is to present peptides derived from the proteins of the challenge virus to the immune system and to engage vaccine-trained T cells to respond. Due to the tight-fit nature of the interaction between virus-derived peptides and the HLA, changes in amino acid sequence of a challenge strain may interfere with the ability of a given peptide to bind to the HLA molecule, preventing recognition of the challenge strain by T cell clones raised against a clade B vaccine construct. Sequence modifications at the amino acid level may affect the recognition of the epitope in three ways: (1) by affecting intracellular processing, (2) by interfering with binding (of the peptide) to major histocompatibility (such as major histocompatibility complex (MHC) or HLA) molecules and presentation of the peptide-HLA complex at the antigen presenting-cell surface, and (3) by interfering with binding of the epitope to the T cell receptor (TCR) (Germain & Margulies, 11 Ann. Rev. Immunol. 403 (1993); Falk *et al.*, 351 Nature 290 (1991)). Thus, the impact of HIV variation at the molecular level may be to diminish cross-clade protection by a vaccine that does not contain CTL epitopes that are conserved across strains of HIV, or epitopes that are more representative of non-B clades.

Many studies of cross-clade recognition of HIV epitopes have been carried out (*see*, Wilson *et al.*, 14(11) AIDS Res. Hum. Retroviruses 925-37 (1998); McAdam *et al.*,

12(6) AIDS .571-9 (1998); Lynch *et al.*, 178(4) J Infect Dis. 1040-6 (1998); Boyer *et al.*, 95 Dev. Biol. Stand. 147-53 (1998); Cao *et al.*, 71(11) J. Virol. 8615-23 (1997); Durali *et al.*, 72(5) Virol. 3547 53 (1998)). In general, these studies often used whole-gene, *vaccinia*-expressed constructs to probe CTL lines from HIV-1 infected or HIV-1 vaccinated volunteers for CTL responses. What appeared to be cross-clade recognition by CTL in these experiments, may have been recognition of CTL epitopes that are conserved within the large gene constructs cloned into the *vaccinia* constructs and into the vaccine strain (or the autologous strain). Where responses to specific peptides, and their altered sequences in other HIV strains, have been tested, and the peptides have been mapped, some studies have shown a lack of cross-strain recognition (Dorrel *et al.*, *HIV Vaccine Development Opportunities And Challenges Meeting*, Abstract 109 (Keystone, Colorado, January 1999)). Studies of virus escape from CTL recognition carried out on HIV-1 infected individuals have also shown that viral variation at the amino acid level may abrogate effective CTL responses (Koup, 180 J. Exp. Med. 779 (1994); Dai *et al.*, 66 J. Virol. 3151 (1992); Johnson *et al.*, 175 J. Exp. Med. 961 (1992)).

As yet, no single HIV strain has been found that will stimulate effective HLA-restricted immune response against a wide range of HIV strains. Thus, a need remains in the art for a "world clade" vaccine.

SUMMARY OF THE INVENTION

The invention provides HIV vaccine candidate peptides, including the HIV peptides shown in any of FIG. 2 (SEQ ID NO:1-27), TABLES 6-31 (SEQ ID NO: 28-626); and FIGS. 6-9 and TABLE 1-4 (SEQ ID NO:627-672). The invention also provides an HIV vaccine, which is an HIV peptide in an immunologically acceptable excipient, such as any of the vaccine carriers known in the medical arts. In one aspect of the invention, the HIV vaccine candidates have "evolved" due to gene shuffling *in vitro* for inclusion of "cross-clade" characteristics.

The invention also provides a method for identifying HIV vaccine candidates that could be presented in the context of more than one HLA, due to the creation of promiscuous epitopes by gene shuffling. Cross-clade HIV peptides are identified. A "cross-clade" HIV peptides is an HIV peptide conserved across several HIV strains having different MHC binding potential. The HIV strains are likely to be presented by MHC molecules representing the most prevalent human HLA alleles. Next, the identified HIV peptides are analyzed for being putative ligands for HLA alleles. Then, HIV peptides that are putative ligands for highly prevalent HLA are as being HIV vaccine candidates. In one embodiment, the cross-clade HIV peptides belong to a consensus sequence obtained from the Los Alamos HIV Sequence Database.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a histogram showing the distribution of the number of HIV-1 isolates in which 8-mer to 11-mer peptides predicted to bind (A) and (b) HLA-B27 are exactly conserved.

FIG. 2 is a table showing the results for the 8-mer to 11-mer peptides for analysis. The second and third columns shows the estimated binding probability for peptides with EpiMatrix scores at least as high as these peptides. The fourth and fifth columns give the highest fold-change in MFI at any concentrations if over 1.3. The sixth column indicates whether the peptide has been published as a known epitope restricted to the appropriate allele. Parentheses indicate that the peptide is contained within an epitope of unknown restriction. The seventh column indicates the protein of origin. The eighth column indicates the number of isolate sequences containing this exact amino acid sequence. The ninth column indicates the approximate position of this ligand relative to the LAI reference strain. The tenth through fifteenth columns indicate whether any of the sequences in which the peptide is conserved are designated as belonging to clades A-E or other clade.

FIG. 3 is a description of the project outline for identifying regional HIV vaccine candidate peptides.

FIG. 4 is a pie chart showing the results of methods for HLA-A allele selection.

FIG. 5 is a pie chart showing the results of methods for HLA-B allele selection.

FIG. 6 is a table showing EpiMatrix predictions and binding results for B7.

FIG. 7 is a table showing EpiMatrix predictions and binding results for B37.

FIG. 8 is a table showing EpiMatrix predictions and binding results for A2.

FIG. 9 is a table showing EpiMatrix predictions and binding results for A11.

FIG. 10 is a description of the methods T2 binding assay.

FIG. 11 is a bar graph showing the clustering of putative MHC ligands in env. At left, the number of putative ligands discovered to be both conserved across clades and likely to bind to at least one human class I MHC is shown by location in a "consensus" sequence obtained from the Los Alamos HIV Sequence Database. This analysis demonstrates regions of distinct clustering. Such regions will be analyzed for representation of HLA alleles. Regions that contain clusters of putative ligands representing highly prevalent HLA were of interest for vaccine development.

DETAILED DESCRIPTION OF THE INVENTION

Vaccines can include any one of the HIV vaccine candidate peptides disclosed below, either alone, in combination with suitable carriers, linked to carrier proteins, or expressed from a polynucleotide, such as a "naked DNA" vaccine. The peptides can be administered to a host for treatment of HIV. The peptides can also be used to enhance immunologic function.

Peptides. The HIV vaccine candidate peptides can be produced by well known chemical procedures, such as solution or solid-phase peptide synthesis, or semi-synthesis in solution beginning with protein fragments coupled through conventional solution methods, as described by Dugas & Penney, *Bioorganic Chemistry*, 54-92 (Springer-Verlag, New York, 1981). For example, peptides can be synthesized by solid-phase methodology utilizing an PE-Applied Biosystems 430A peptide synthesizer (commercially available from Applied Biosystems, Foster City, CA) and synthesis cycles

supplied by Applied Biosystems. Boc amino acids and other reagents are commercially available from PE-Applied Biosystems and other chemical supply houses. Sequential Boc chemistry using double couple protocols are applied to the starting p-methyl benzhydryl amine resins for the production of C-terminal carboxamides. After synthesis and cleavage, purification is accomplished by reverse-phase C18 chromatography (Vydac) column in 0.1% TFA with a gradient of increasing acetonitrile concentration. The solid phase synthesis could also be accomplished using the FMOC strategy and a TFA/scavenger cleavage mixture.

When produced by conventional recombinant means, (*described below*) the HIV vaccine candidate peptide can be isolated either from the cellular contents by conventional lysis techniques or from cell medium by conventional methods, such as chromatography (*see, e.g.*, Sambrook *et al., Molecular Cloning. A Laboratory Manual.*, 2d Edition (Cold Spring Harbor Laboratory, New York (1989).

The general construction and use of synthetic HIV peptides is disclosed in United States patents 5,817,318 and 5,876,731, the contents of which are incorporated by reference.

In one embodiment, the HIV vaccine candidate peptide has a maximum size of 50 amino acids in length and a minimum size of 8 amino acids (for the relevant SEQ ID NOS) to 11 amino acids (for other relevant SEQ ID NOS). The peptide can be any size between the minimum to maximum size, and one HIV vaccine candidate peptide can be of a given size independently of another HIV vaccine candidate peptide. For example one HIV vaccine candidate peptide can be 25 amino acids in length while another HIV vaccine candidate peptide is 45 amino acids in length.

Peptides as antigens. The HIV vaccine candidate peptides are useful as antigens for raising anti-HIV immune responses, such as T cell responses (cytotoxic T cells or T helper cells). An "antigen" is a molecule or a portion of a molecule capable of stimulating an immune response, which is additionally capable of inducing an animal or human to produce antibody capable of binding to an epitope of that antigen. An "epitope" is that

portion of any molecule capable of being recognized by and bound by an MHC molecule and recognized by a T cell or bound by an antibody. An antigen can have one or more than one epitope. The specific reaction indicates that the antigen will react, in a highly selective manner, with its corresponding MHC and T cell, or antibody and not with the multitude of other antibodies which can be evoked by other antigens.

A peptide is "immunologically reactive" with an T cell or antibody when it binds to an MHC and is recognized by a T cell or binds to an antibody due to recognition (or the precise fit) of a specific epitope contained within the peptide. Immunological reactivity can be determined by measuring T cell response *in vitro* or by antibody binding, more particularly by the kinetics of antibody binding, or by competition in binding using as competitors a known peptides containing an epitope against which the antibody or T cell response is directed. The techniques for determining whether a peptide is immunologically reactive with an T CELL or with an antibody are known in the art. The peptides can be screened for efficacy by *in vitro* and *in vivo* assays. Such assays employ immunization of an animal, *e.g.*, a rabbit or a primate, with the peptide, and evaluation of titers antibody to HIV-1 or to synthetic detector peptides corresponding to variant HIV sequences (*see*, EXAMPLE 3, and FIG. 10). Methods of determining the spatial conformation of amino acids are known in the art, and include, for example, x-ray crystallography and 2-dimensional nuclear magnetic resonance.

Polynucleotides encoding the peptides. Polynucleotides can encode HIV vaccine candidate peptides, including peptides fused to carrier proteins. HIV vaccine candidate peptides can be encoded by either a synthetic or recombinant polynucleotide. The term "recombinant" refers to the molecular biological technology for combining polynucleotides to produce useful biological products, and to the polynucleotides and peptides produced by this technology. The polynucleotide can be a recombinant construct (such as a vector or plasmid) which contains the polynucleotide encoding the HIV vaccine candidate peptide or fusion protein under the operative control of polynucleotides encoding regulatory elements such as promoters, termination signals, and the like. "Operatively

linked" refers to a juxtaposition wherein the components so described are in a relationship permitting them to function in their intended manner. A control sequence operatively linked to a coding sequence is ligated such that expression of the coding sequence is achieved under conditions compatible with the control sequences. "Control sequence" refers to polynucleotide sequences which are necessary to effect the expression of coding and non-coding sequences to which they are ligated. Control sequences generally include promoter, ribosomal binding site, and transcription termination sequence. In addition, "control sequences" refers to sequences which control the processing of the peptide encoded within the coding sequence; these can include, but are not limited to sequences controlling secretion, protease cleavage, and glycosylation of the peptide. The term "control sequences" is intended to include, at a minimum, components whose presence can influence expression, and can also include additional components whose presence is advantageous, for example, leader sequences and fusion partner sequences. A "coding sequence" is a polynucleotide sequence which is transcribed and translated into a polypeptide. Two coding polynucleotides are "operably linked" if the linkage results in a continuously translatable sequence without alteration or interruption of the triplet reading frame. A polynucleotide is operably linked to a gene expression element if the linkage results in the proper function of that gene expression element to result in expression of the HIV vaccine candidate coding sequence. "Transformation" is the insertion of an exogenous polynucleotide (*i.e.*, a "transgene") into a host cell. The exogenous polynucleotide is integrated within the host genome. A polynucleotide is "capable of expressing" a HIV vaccine candidate peptide if it contains nucleotide sequences which contain transcriptional and translational regulatory information and such sequences are "operably linked" to polynucleotide which encode the HIV vaccine candidate peptide. A polynucleotide that encodes a peptide coding region can be then amplified, for example, by preparation in a bacterial vector, according to conventional methods, for example, described in the standard work Sambrook *et al.*, *Molecular Cloning: A Laboratory Manual* (Cold Spring Harbor Press 1989). Expression vehicles include plasmids or other

vectors. Prokaryotic vectors known in the art include plasmids such as those capable of replication in E. coli (such as, for example, pBR322, ColE1, pSC101, pACYC184, πVX).

The polynucleotide encoding the HIV vaccine candidate peptide can be prepared by chemical synthesis methods or by recombinant techniques. The polypeptides can be prepared conventionally by chemical synthesis techniques, such as described by Merrifield, 85 J. Amer. Chem. Soc. 2149-2154 (1963) (*see,* Stemmer *et al*, 164 Gene 49 (1995)). Synthetic genes, the *in vitro* or *in vivo* transcription and translation of which will result in the production of the protein can be constructed by techniques well known in the art (*see* Brown et al., 68 Methods in Enzymology 109-151 (1979)). The coding polynucleotide can be generated using conventional DNA synthesizing apparatus such as the Applied Biosystems Model 380A or 380B DNA synthesizers (commercially available from Applied Biosystems, Inc., 850 Lincoln Center Drive, Foster City, Calif. 94404).

Alternatively, systems for cloning and expressing HIV vaccine candidate peptides include various microorganisms and cells which are well known in recombinant technology. These include, for example, various strains of *E. coli, Bacillus, Streptomyces,* and *Saccharomyces*, as well as mammalian, yeast and insect cells. Suitable vectors are known and available from private and public laboratories and depositories and from commercial vendors. *See*, Sambrook *et al.*, *Molecular Cloning: A Laboratory Manual* (Cold Spring Harbor Press 1989). *See, also* PCT International patent application WO 94/01139). These vectors permit infection of patient's cells and expression of the synthetic gene sequence in vivo or expression of it as a peptide or fusion protein *in vitro*.

Polynucleotide gene expression elements useful for the expression of cDNA encoding peptides include, but are not limited to (a) viral transcription promoters and their enhancer elements, such as the SV40 early promoter, Rous sarcoma virus LTR, and Moloney murine leukemia virus LTR; (b) splice regions and polyadenylation sites such as those derived from the SV40 late region; and (c) polyadenylation sites such as in SV40. Recipient cells capable of expressing the HIV vaccine candidate gene product are then transfected. The transfected recipient cells are cultured under conditions that permit

expression of the HIV vaccine candidate gene products, which are recovered from the culture. Host mammalian cells, such as Chinese Hamster ovary cells (CHO) or COS-1 cells, can be used. These hosts can be used in connection with poxvirus vectors, such as vaccinia or swinepox. Suitable non-pathogenic viruses which can be engineered to carry the synthetic gene into the cells of the host include poxviruses, such as vaccinia, adenovirus, retroviruses and the like. A number of such non-pathogenic viruses are commonly used for human gene therapy, and as carrier for other vaccine agents, and are known and selectable by one of skill in the art. The selection of other suitable host cells and methods for transformation, culture, amplification, screening and product production and purification can be performed by one of skill in the art by reference to known techniques (*see, e.g.,* Gething & Sambrook, 293 Nature 620-625 (1981)). Another preferred system includes the baculovirus expression system and vectors.

The general construction and use of polynucleotides encoding for non-infectious, replication-defective, self-assembling HIV-1 viral particles containing HIV antigenic markers is disclosed in United States patent 5,866,320, the contents of which are incorporated by reference.

The polynucleotide encoding the HIV vaccine candidate peptide can be used in a variety of ways. For example, a polynucleotide can express the HIV vaccine candidate peptide *in vitro* in a host cell culture. The expressed HIV vaccine candidate peptide immunogens, after suitable purification, can then be incorporated into a pharmaceutical reagent or vaccine (*described below*).

Alternatively, the polynucleotide encoding the HIV vaccine candidate peptide immunogen can be administered directly into a human as so-called "naked DNA" to express the peptide immunogen *in vivo* in a patient. (*see*, Cohen, 259 Science 1691-1692 (1993); Fynan *et al.*, 90 Proc. Natl. Acad. Sci. USA, 11478-82 (1993); and Wolff *et al.*, 11 BioTechniques 474-485 (1991). The polynucleotide encoding the HIV vaccine candidate peptide immunogen can be used for direct injection into the host. This results in

expression of the HIV vaccine candidate peptide by host cells and subsequent presentation to the immune system to induce anti-HIV antibody formation *in vivo*.

Determinations of the sequences for the polynucleotide coding region that codes for the HIV vaccine candidate peptides described herein can be performed using commercially available computer programs, such as DNA Strider and Wisconsin GCG. Owing to the natural degeneracy of the genetic code, the skilled artisan will recognize that a sizable yet definite number of DNA sequences can be constructed which encode the claimed peptides (*see*, Watson *et al.*, *Molecular Biology of the Gene*, 436-437 (the Benjamin/Cummings Publishing Co. 1987)).

Treatment of HIV infection. The method for reducing the viral levels of HIV-1 involves exposing a human to a HIV vaccine candidate peptides, actively inducing antibodies that react with HIV-1, and impairing the multiplication of the virus *in vivo*. This method is appropriate for an HIV-1 infected subject with a competent immune system, or an uninfected or recently infected subject. The method induces antibodies which react with HIV-1 , which antibodies reduce viral multiplication during any initial acute infection with HIV-1 and minimize chronic viremia leading to AIDS. This method also lowers chronic viral multiplication in infected subjects, minimizing progression to AIDS. In other words, in already infected patients, this method of reduction of viral levels can reduce chronic viremia and progression to AIDS. In uninfected humans, this administration of the peptides of the invention can reduce acute infection and thus minimize chronic viremia leading to progression to AIDS.

The terms "treating," "treatment," and the like are used herein to mean obtaining a desired pharmacologic or physiologic effect. The effect can be prophylactic in terms of completely or partially preventing a disorder or sign or symptom thereof, or can be therapeutic in terms of a partial or complete cure for a disorder and/or adverse effect attributable to the disorder. "Treating" as used herein covers any treatment and includes: (a) preventing a disorder from occurring in a subject that can be predisposed to a disorder, but has not yet been diagnosed as having it; (b) inhibiting the disorder, *i.e.*, arresting its

development; or (c) relieving or ameliorating the disorder, *e.g.*, cause regression of HIV infection or AIDS. An "effective amount" or "therapeutically effective amount" is the amount sufficient to obtain the desired physiological effect, *e.g.*, treatment of HIV. An effective amount of the HIV vaccine candidate peptide or vector expressing HIV vaccine candidate peptides is generally determined by the physician in each case on the basis of factors normally considered by one skilled in the art to determine appropriate dosages, including the age, sex, and weight of the subject to be treated, the condition being treated, and the severity of the medical condition being treated. Among such patients suitable for treatment with this method are HIV-1 infected patients who are immunocompromised by disease and unable to mount a strong immune response. In later stages of HIV infection, the likelihood of generating effective titers of antibodies is less, due to the immune impairment associated with the disease. Also among such patients are HIV-1 infected pregnant women, neonates of infected mothers, and unimmunized patients with putative exposure (*e.g.*, a human who has been inadvertently "stuck" with a needle used by an HIV-1 infected human).

Method of administration. HIV vaccine candidate peptides can be administered in a variety of ways, orally, topically, parenterally *e.g.* subcutaneously, intraperitoneally, by viral infection, intravascularly, *etc.* Depending upon the manner of introduction, the HIV vaccine candidate peptides can be formulated in a variety of ways. The concentration of HIV vaccine candidate peptides in the formulation can vary from about 0.1-100 wt.%.

The amount of the HIV vaccine candidate peptide or polynucleotides of the invention present in each vaccine dose is selected with regard to consideration of the patient's age, weight, sex, general physical condition and the like. The amount of HIV vaccine candidate peptide required to induce an immune response, preferably a protective response, or produce an exogenous effect in the patient without significant adverse side effects varies depending upon the pharmaceutical composition employed and the optional presence of an adjuvant. Generally, for the compositions containing HIV vaccine candidate peptide, each dose will comprise between about 50 μg to about 1 mg of the

HIV vaccine candidate peptide immunogens/ml of a sterile solution. A more preferred dosage can be about 200 μg of HIV vaccine candidate peptide immunogen. Other dosage ranges can also be contemplated by one of skill in the art. Initial doses can be optionally followed by repeated boosts, where desirable. The method can involve chronically administering the HIV vaccine candidate peptide composition. For therapeutic use or prophylactic use, repeated dosages of the immunizing compositions can be desirable, such as a yearly booster or a booster at other intervals. The dosage administered will, of course, vary depending upon known factors such as the pharmacodynamic characteristics of the particular agent, and its mode and route of administration; age, health, and weight of the recipient; nature and extent of symptoms, kind of concurrent treatment, frequency of treatment, and the effect desired. Usually a daily dosage of active ingredient can be about 0.01 to 100 mg/kg of body weight. Ordinarily 1.0 to 5, and preferably 1 to 10 mg/kg/day given in divided doses 1 to 6 times a day or in sustained release form is effective to obtain desired results.

The HIV vaccine candidate peptide can be employed in chronic treatments for subjects at risk of acute infection due to needle sticks or maternal infection. A dosage frequency for such "acute" infections may range from daily dosages to once or twice a week i.v. or i.m., for a duration of about 6 weeks. The peptides can also be employed in chronic treatments for infected patients, or patients with advanced HIV. In infected patients, the frequency of chronic administration can range from daily dosages to once or twice a week i.v. or i.m., and may depend upon the half-life of the immunogen (*e.g.*, about 7-21 days). However, the duration of chronic treatment for such infected patients is anticipated to be an indefinite, but prolonged period.

For such therapeutic uses, the HIV vaccine candidate peptide formulations and modes of administration are substantially identical to those described specifically above and can be administered concurrently or simultaneously with other conventional therapeutics for the viral infection.

Immunologically acceptable carrier. HIV vaccine candidate peptides can be administered either as individual therapeutic agents or in combination with other therapeutic agents. HIV vaccine candidate peptides can be administered alone, but are generally administered with a pharmaceutical carrier selected on the basis of the chosen route of administration and standard pharmaceutical practice. The vaccine can further comprise suitable, *i.e.*, physiologically acceptable, carriers--preferably for the preparation of injection solutions--and further additives as usually applied in the art (stabilizers, preservatives, etc.), as well as additional drugs. The patients can be administered a dose of approximately 1 to 10 μg/kg body weight, preferably by intravenous injection once a day. For less threatening cases or long-lasting therapies the dose can be lowered to 0.5 to 5 μg/kg body weight per day. The treatment can be repeated in periodic intervals, *e.g.*, two to three times per day, or in daily or weekly intervals, depending on the status of HIV-1 infection or the estimated threat of an individual of getting HIV infected.

For parenteral administration, peptides of the invention can be formulated as a solution, suspension, emulsion or lyophilized powder in association with a pharmaceutically acceptable parenteral vehicle. Examples of such vehicles are water, saline, Ringer's solution, dextrose solution, and 5% human serum albumin. Liposomes and nonaqueous vehicles such as fixed oils can also be used. The vehicle or lyophilized powder can contain additives that maintain isotonicity (*e.g.*, sodium chloride, mannitol) and chemical stability (*e.g.*, buffers and preservatives). The formulation is sterilized by commonly used techniques. Suitable pharmaceutical carriers are described in the most recent edition of *Remington's Pharmaceutical Sciences*, a standard reference text in this field of art. For example, a parenteral composition suitable for administration by injection is prepared by dissolving 1.5% by weight of active ingredient in 0.9% sodium chloride solution. The preparation of these pharmaceutically acceptable compositions, having appropriate pH isotonicity, stability and other conventional characteristics is within the skill of the art.

The vaccine composition can include as the active agents, one of the following above-described components: (a) a HIV vaccine candidate peptide immunogen (These immunogens can be in the form of recombinant proteins. Alternatively, they can be in the form of a mixture of carrier protein conjugates.); (b) a polynucleotide encoding a HIV vaccine candidate; (c) a recombinant virus carrying the synthetic gene or molecule; and (d) a bacteria carrying the HIV vaccine candidate. The selected active component is present in a pharmaceutically acceptable carrier, and the composition can contain additional ingredients.

Formulations containing the HIV vaccine candidate peptide can contain other active agents, such as adjuvants and immunostimulatory cytokines, such as IL-12 and other well-known cytokines, for the peptide compositions.

Suitable pharmaceutically acceptable carriers for use in an immunogenic composition are well known to those of skill in the art. Such carriers include, for example, saline, a selected adjuvant, such as aqueous suspensions of aluminum and magnesium hydroxides, liposomes, oil in water emulsions, and others.

Carrier protein. HIV vaccine candidate peptide immunogens can be linked to a suitable carrier in order to improve the efficacy of antigen presentation to the immune system. Such carriers can be, for instance, organic polymers. A carrier protein can enhance the immunogenicity of the peptide immunogen. Such a carrier can be a larger molecule which has an adjuvant effect. Exemplary conventional protein carriers include, keyhole limpet hemocyan, *E. coli* DnaK protein, galactokinase (galK, which catalyzes the first step of galactose metabolism in bacteria), ubiquitin, α-mating factor, β-galactosidase, and influenza NS-1 protein. Toxoids (*i.e.*, the sequence which encodes the naturally occurring toxin, with sufficient modifications to eliminate its toxic activity) such as diphtheria toxoid and tetanus toxoid can also be employed as carriers. Similarly a variety of bacterial heat shock proteins, *e.g.*, mycobacterial hsp-70 can be used. Glutathione reductase (GST) is another useful carrier. One of skill in the art can readily select an appropriate carrier.

Viruses can be modified by recombinant DNA technology such as, *e.g.* rhinovirus, poliovirus, vaccinia, or influenzavirus, *etc.* The peptide can be linked to a modified, *i.e.*, attenuated or recombinant virus such as modified influenza virus or modified hepatitis B virus or to parts of a virus, *e.g.*, to a viral glycoprotein such as, *e.g.*, hemagglutinin of influenza virus or surface antigen of hepatitis B virus, in order to increase the immunological response against HIV-1 viruses and/or infected cells.

The HIV vaccine candidate peptides can be in fusion proteins, wherein they are linked to a suitable carrier which might be a recombinant or attenuated virus or a part of a virus such as, *e.g.*, the hemagglutinin of influenza virus or the surface antigen of hepatitis B virus, or another suitable carrier including other viral surface proteins, *e.g.*, surface proteins of rhinovirus, poliovirus, sindbis virus, coxsackievirus, *etc.*, for efficient presentation of the antigenic site(s) to the immune system. In some cases, the antigenic fragments might, however, also be purely, *i.e.*, without attachment to a carrier, applied in an analytical or therapeutical program.

Naked DNA vaccine. Alternatively, polynucleotides can be designed for direct administration as "naked DNA". Suitable vehicles for direct DNA, plasmid polynucleotide, or recombinant vector administration include, without limitation, saline, or sucrose, protamine, polybrene, polylysine, polycations, proteins, calcium phosphate, or spermidine. *See e.g*, PCT International patent application WO 94/01139. As with the immunogenic compositions, the amounts of components in the DNA and vector compositions and the mode of administration, *e.g.*, injection or intranasal, can be selected and adjusted by one of skill in the art. Generally, each dose will comprise between about 50 μg to about 1 mg of immunogen-encoding DNA per ml of a sterile solution.

For recombinant viruses containing the coding polynucleotide, the doses can range from about 20 to about 50 ml of saline solution containing concentrations of from about $1x10^7$ to $1x10^{10}$ pfu/ml recombinant virus of the invention. One human dosage is about 20 ml saline solution at the above concentrations. However, it is understood that one of skill

in the art can alter such dosages depending upon the identity of the recombinant virus and the make-up of the immunogen that it is delivering to the host.

The amounts of the commensal bacteria carrying the synthetic gene or molecules to be delivered to the patient will generally range between about 10^3 to about 10^{12} cells/kg. These dosages, will of course, be altered by one of skill in the art depending upon the bacterium being used and the particular composition containing immunogens being delivered by the live bacterium.

Antibodies. An antibody directed against a HIV vaccine candidate peptide is also an aspect of this invention. Polyclonal antibodies are produced by immunizing a mammal with a peptide immunogen. Suitable mammals include primates, such as monkeys; smaller laboratory animals, such as rabbits and mice, as well as larger animals, such as horse, sheep, and cows. Such antibodies can also be produced in transgenic animals. However, a desirable host for raising polyclonal antibodies to a composition of this invention includes humans. The polyclonal antibodies raised are isolated and purified from the plasma or serum of the immunized mammal by conventional techniques. Conventional harvesting techniques can include plasmapheresis, among others. Such polyclonal antibodies can themselves be employed as pharmaceutical compositions of this invention. Alternatively, other forms of antibodies can be developed using conventional techniques, including monoclonal antibodies, chimeric antibodies, humanized antibodies and fully human antibodies (*see, e.g.*, United States patent 4,376,110; Ausubel *et al.*, *Current Protocols in Molecular Biology* (Greene Publishing Assoc. and Wiley Interscience, N.Y., 1992); Harlow & Lane, *Antibodies: a Laboratory Manual*, (Cold Spring Harbor Laboratory, 1988); Queen *et al.*, 86 Proc. Nat'l. Acad. Sci. USA 10029-10032 (1989); Hodgson *et al.*, 9 Bio/Technology 421 (1991); PCT International patent application WO 92/04381 and PCT International patent application WO 93/20210. Other antibodies can be developed by screening hybridomas or combinatorial libraries, or antibody phage displays (Huse *et al.*, 246 Science 1275-1281 (1988) using the polyclonal or monoclonal antibodies produced

according to this invention and the amino acid sequences of the primary or optional immunogens.

The term "antibody" includes polyclonal antibodies, monoclonal antibodies (mAbs), chimeric antibodies, anti-idiotypic (anti-Id) antibodies to antibodies that can be labeled in soluble or bound form, as well as fragments, regions or derivatives thereof, provided by any known technique, such as, but not limited to enzymatic cleavage, peptide synthesis or recombinant techniques. An "antigen binding region" is that portion of an antibody molecule which contains the amino acid residues that interact with an antigen and confer on the antibody its specificity and affinity for the antigen. The antibody region includes the framework amino acid residues necessary to maintain the proper conformation of the antigen-binding residues.

Computer Implementation. Aspects of the invention may be implemented in hardware or software, or a combination of both. However, preferably, the algorithms and processes of the invention are implemented in one or more computer programs executing on programmable computers each comprising at least one processor, at least one data storage system (including volatile and non-volatile memory and/or storage elements), at least one input device, and at least one output device. Program code is applied to input data to perform the functions described herein and generate output information. The output information is applied to one or more output devices, in known fashion.

Each program may be implemented in any desired computer language (including machine, assembly, high level procedural, or object oriented programming languages) to communicate with a computer system. In any case, the language may be a compiled or interpreted language.

Each such computer program is preferably stored on a storage media or device (*e.g.*, ROM, CD-ROM, tape, or magnetic diskette) readable by a general or special purpose programmable computer, for configuring and operating the computer when the storage media or device is read by the computer to perform the procedures described herein. The inventive system may also be considered to be implemented as a computer-

readable storage medium, configured with a computer program, where the storage medium so configured causes a computer to operate in a specific and predefined manner to perform the functions described herein.

The details of one or more embodiments of the invention are set forth in the accompanying description. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the invention, the preferred methods and materials are now described. Other features, objects, and advantages of the invention will be apparent from the description and from the claims. In the specification and the appended claims, the singular forms include plural referents unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. All patents and publications cited in this specification are incorporated by reference.

The following EXAMPLES are presented in order to more fully illustrate the preferred embodiments of the invention. These examples should in no way be construed as limiting the scope of the invention, as defined by the appended claims.

EXAMPLE 1
PREDICTION OF WELL-CONSERVED HIV-1 LIGANDS USING A MATRIX-BASED ALGORITHM, EPIMATRIX

Summary. This EXAMPLE was undertaken to identify new human leukocyte antigens (HLA) ligands from human immunodeficiency virus type 1 (HIV-1) which are highly conserved across HIV-1 clades and which may serve to induce cross-reactive cytotoxic T lymphocytes (CTLs). EpiMatrix was used to predict putative ligands from HIV-1 for HLA-A2 and HLA-B27. Twenty-six peptides that were both likely to bind and also highly conserved across HIV-1 strains in the Los Alamos HIV sequence database were selected for binding assays using the T2 stabilization assay. Two peptides that were also highly likely to bind (forA2 and B27, as determined by EpiMatrix) and well conserved

across HIV-1 strains, and had previously been described to bind in the publicized literature, were also selected to serve as positive controls for the assays. Ten new major histocompatibility complex (MHC) ligands were identified among the 26 study peptides. The control peptides bound, as expected. These data confirm that EpiMatrix can be used to screen HIV-1 protein sequences for highly conserved regions that are likely to bind to MHC and may prove to be highly conserved HIV-1 CTL epitopes.

Introduction. This EXAMPLE is a prospective design of multivalent HIV immunogens tailored to reflect the diversity of HIV isolates and to promote cross-clade protection in settings where more than one HIV strain and more than one HIV clade is being transmitted. This EXAMPLE explored the use of EpiMatrix, a matrix-based algorithm for T-cell epitope prediction, to prospectively identify conserved class I-restricted MHC ligands and potential CTL epitopes. EpiMatrix and other computer-driven algorithms that predict putative MHC ligands and CTL epitopes (Davenport *et al.*, 42 Immunogenetics 392-7 (1995); Hammer *et al.*, 180 J. Exp. Med. 2353-8 (1994); Flackenstein *et al.*, 240 Eur. J. Biochem. 71-7 (1996)) place the prospective design of a novel HIV-1 vaccine with these critically important characteristics within reach.

Such prospectively designed vaccines are based on the central role of CTL in the host immune response to HIV-1, and the understanding that the first step in the search for HIV-1 CTL epitopes may be to identify peptides that bind to the host major histocompatibility complex (MHC). Recognition of such MHC ligands by CTL is dependent on the presentation of the T-cell epitope to the T cells in the context of MHC molecules. Peptides presented in conjunction with class I MHC molecules (to T cells) are derived from foreign or self-protein antigens that have been processed in the cytoplasm. The peptides bind to MHC molecules in a linear fashion; the binding is determined by the interaction of the peptide's amino acid side-chains with binding pockets in the MHC molecule. Binding of peptides to MHC molecules is constrained by the nature of the

side-chains; only selected peptides will fit the constraints of any given MHC molecule's binding pockets.

The characteristics of peptides that are likely to bind to a given MHC can be directly deduced from pooled sequencing data (from peptides bulk-eluted off MHC molecules), from MHC binding peptide libraries. The TB/HIV Research Lab has developed a method to describe the relative promotion or inhibition of binding afforded by each position in a peptide to the MHC of interest.

EpiMatrix ranks all 10 amino acid long segments from any protein sequence by estimated probability of binding to a given MHC, by comparing the sequence to a matrix. The estimated binding probability (EBP) is derived by comparing the EpiMatrix score to those of known binders and presumed non-binders. Retrospective studies have demonstrated that EpiMatrix accurately predicts MHC Ligands (DeGroot *et al.*, 7 Human Retroviruses 139 (1997); Jesdale *et al.*, in *Vaccines '97.* (Cold Spring Harbor Press, Cold Spring Harbor, 1997).

In this EXAMPLE, we implemented EpiMatrix to examine the sequences of HIV-1 strains published on the 1995 version of the Los Alamos National Laboratory HIV Sequence database. We identified conserved regions and then examined these for their potential to bind to one of two MHC alleles (A2 and B27). We prospectively identified conserved MHC ligands which may be useful for HIV-1 vaccine development.

Generation of an MHC binding matrix motif. Various methods were used in the generation of MHC binding matrix motifs. Briefly, independent sources of information on the relative promotion or inhibition of each amino acid in each position are identified. For each source of information, an estimation of the relative promotion or inhibition of binding is quantified. In a generic sense, this quantification is based on a relative rate calculation, the rate of an amino acid in a given position relative to its median rate across all positions. These matrix motifs, based on single sources of information (such as a list of known ligands (Huczko *et al.*, 151 J. Immunol. 2572 (1993)); pooled sequencing of naturally elated peptides (Kubo et al., 152 J. Immunol. 3913-24 (1993)) peptide side-chain scanning

techniques (Hammer *et al.*, 180 J. Exp. Med. 2353-8 (1994)), or the identification of ligands with specific characteristics through random phage techniques (Flackenstein *et al.*, 240 Eur. J. Biochem. 71-7 (1996)), are then combined in a way which attempts to maximize the resultant matrix motif's ability to separate a list of known ligands from the other peptides contained within their original sequences. The two matrix motifs based on single datasets with the best individual predictive power (assessed using the Kruskal—Wallis non-parametric test) are first combined with each other. The best resultant of these two was then combined with the third most individually predictive, and so on. The result of this process was then combined with the method of Parker *et al.*, 152 J. Immunol. 163-75 (1994) to achieve a final predictive matrix motif for each MHC allele.

Generating an EpiMatrix score. Each putative MHC binding region within a given protein sequence is scored by estimating the relative promotion or inhibition of binding for each amino acid, and summing these to create a summary score for the entire peptide. Higher EpiMatrix scores indicate greater MHC binding potential. After comparing the score to the scores of known MHC ligands, an "estimated binding probability" or EBP, is estimated. The EBP describes the proportion of peptides with EpiMatrix scores as high or higher that will bind to a given MHC molecule.

EBP is derived from the EpiMatrix score by determining how many published ligands for the allele would earn that same score or a higher score (a measure of sensitivity). EBPs range from 100% (highly likely to bind) to less than 1% (very unlikely to bind). The majority of 10mers in any one protein sequence fall below the 1% estimated binding probability for any given MHC binding matrix.

Selection of peptides. For each protein, env, pol, nef, and tat was analyzed independently. The sequence for each HIV-1 isolate in the Los Alamos HIV sequence database (Korber & Meyers, eds, *HIV Sequence Database, Los Alamos HIV Database, 1995.* (Los Alamos National Laboratories, New Mexico, 1995) was divided into ten amino acid long strings which overlapped by nine. These 10-mer strings were then compared to the A2 and B7 MHC binding matrix motifs (EpiMatrix version 1.0). Peptides

that scored higher than 50% EBP were selected. Each of these putative ligands was compared to all the others using a spreadsheet and command macro which orders the strings from those which are common to many of the sequences to those which were unique (FIG 1). Strings that were present in "more" HIV-1 isolates (the exact number depended on the number of isolates available in the LANL database) were selected for the next phase of the analysis. Twenty-eight peptides were selected using this method. One of the selected peptides corresponded to a published CTL epitope, and was selected to serve as a control. An additional peptide selected to serve as a positive control as for this study, KRWIILGLNK, scored lower on the B27 matrix than 50%, however, it was the only available HIV-1 B27 ligand that had been fine-mapped.

The T2 *in vitro* peptide binding assay was performed as recently described by Nijman et al., 23 Eur. J. Immunol. 1215-9 (1993). This assay relies on the ability of exogenously added peptides to stabilize the Class I/β2 microglobulin structure on the surface of TAP-defective cell lines. For these assays, we used the antigen processing mutant cell line T2 transfected with the HLA B27 gene (T2/B27). These cells were cultured in Iscove Modified Dulbecco's Medium (IMDM), 10% fetal bovine serum, and 20 μg/ml gentamycin. A monoclonal antibody to HLA-827 produced by the ATCC 1-HB-119. MEI hybridoma (Ellis *et al.*, 5 Hum. Immunol. 49-59 (1982) was used to assess HLA-B27 expression at the cell surface (indicating peptide binding and stabilization of the B27 molecule). The monoclonal antibody produced by the ATCC HB-82, BB7.2 hybridoma (Parham & Brodsky, 3 Hum. Immunol. 277-99 (1981)) was used to assess HLA-A2 expression at the cell surface.

Three hundred thousand cells in 100 μl of IMDM, 10% FBS, and 20 μg/ml gentamycin medium were incubated with no peptide, or 100 μl synthetic peptide solution overnight at 37°C, in an atmosphere of 5% CO_2. The T2 cell/peptide suspension was pelleted at 1000 rpm. the supernatant was discarded, and the suspension was stained with 100 μl of BB7.2, an HLA-A2 specific mouse monoclonal primary antibody (1 hr at 4°C). Two wells per peptide did not receive the primary antibody, but only the PBS staining

buffer. The cells were washed 3x with cold (4°C) staining butter PBS, 0.5% FBS, 0.02% NaN_3, and stained for 30 min at 4°C with 100 µl FITC-labeled goat anti-mouse immunoglobulin (Pharmingen, 12064-D). The cells were again washed three times and fixed in 1% paraformaldehyde. Fluorescence of viable T2 cells was measured at 488 nm on a FACScan flow cytometer (Becton-Dickinson, NJ).

A total of 12 wells was assayed per peptide (one well each with peptide at 0, 2, 20, and 200 µg/ml were repeated using primary antibody for the molecule the peptide is predicted to bind to, the primary antibody to the molecule the peptide was not predicted to bind to, and no primary antibody).

Analysis and interpretation of binding assays. Peptide binding to MHC molecules stabilizes MHC expression at the cell surface, and can be measured by FACS sorting the cells. The data produced by the FACS analysis represented the mean linear fluorescence (MLF) of 10000 events. We used a cut-off of 1.3-fold greater MFI in any of the three wells with peptide than the control well as the criterion for positive binding.

Results. Twenty-eight peptides were tested in binding assays. Two of the 28 were previously published ligands. Ten peptides induced an increase in the MFI of 1.3-fold or greater (FIG. 2). The published controls bound as expected. Peptides shown here were selected because they were predicted to bind to A2 and not to B27, or *vice versa*. None of the peptides predicted to bind to A2 bound to B27 and *vice versa*.

Conclusion. We performed prospective definition of conserved HIV-1 regions using EpiMatrix version 1.0. Rapid identification of MHC ligands, which can then be tested in T-cell assays, is desirable for HIV-1 vaccine development. Computer-driven analysis of HIV sequences will permit the prospective identification of such conserved CTL epitopes.

Determination of peptides that bind to major history compatibility (MHC) molecules (MHC ligands) can be the first step in the process of identifying T-cell epitopes. Identification of MHC ligands from primary HIV-1 sequences as particularly relevant for HIV vaccine development and immunopathogenesis research. Matrix-based motifs have

been developed to improve on the specificity of anchor-based motifs. The advantage of matrix motifs is that peptides can be given a score that represents the sum of the potential for each ammo acid in the sequence to promote or inhibit binding.

Predicting regions of immunological interest is only the first step to determining whether the region is likely to be recognized by primed T cells, and to be defined as a CTL epitope. Predictions must be confirmed by binding assays, so as to determine whether a peptide representing that region indeed binds to the MHC for which it was predicted (*e.g.*, T2 cell binding assay). Immunogencity of the peptides must also be confirmed by measuring whether CTL recognize the peptide in T-cell assays.

Methods of analysis developed in the TB/HIV Research Lab also permit the comparison of putative MHC ligands across HIV-1 clades and permit the weighting of predictions for the prevalence of HLA alleles in human populations. Utilization of these computer-driven methods will put the prospective identification of cross-clade (cross-reactive) and promiscuous epitopes for HIV-1 vaccine development within reach.

EXAMPLE 2
A REGIONAL HIV VACCINE FOR INDIA

Introduction. India has one of the highest burdens of HIV infection of any country in the world: 4.1 million individuals are already thought to be infected and the epidemic will accelerate over the next decade. The prevalence of selected clades on the Indian sub-continent and the unique genetic make-up (HLA distribution) of the Indian population led to the concept of a region-specific HIV vaccine.

We selected HIV peptides for conservation across HIV-1 strains that have been isolated in India. We then evaluated these peptides for their projected binding capability to selected MHC Class I molecules, using the computer-driven modeling program, EpiMatrix. Twenty eight peptides were identified as highly conserved in the Indian HIV-1 sequences and predicted to bind to MHC Class I (HLA-A0201, -A1101, -B35, -B7) that are prevalent HLA alleles in India.

Analysis. Sixty six HIV-1 sequences from India (55 env, 6 gag, 5 pol) were identified from published literature as having been isolated in India or from individuals who acquired their HIV infection in India. The amino acid sequences were examined for regions conserved in ~50% of the sequences. These peptides were synthesized and tested *in vitro* using an MHC binding assay protocol. CTL assays were also performed. Fluorescence data was analyzed using: (1) a two-factor ANOVA to determine treatment or plate effect, and (2) a multiple comparison to find significant differences between treatment means.

Results. Twenty out of the 28 predicted peptides (71 %) stabilized the MHC Class I molecule for which they were predicted to bind. (p-values < 0.001). The predictive accuracy of the B7 (86%) and B35 (100%) matrices for the EpiMatrix algorithm were slightly better, in this EXAMPLE, than the accuracies of the A11(42%) and A2(57%) matrices. B7 peptides predicted to bind to B35 as well were able to stabilize B35 *in vitro*. B7 Peptides predicted to be unlikely to bind to B35 did not stabilize B35 *in vitro*. The reverse (B35/B7) was also true.

The following TABLES correspond to FIGS. 6-9.

TABLE 1
B7

peptide #	peptide	seq. Used	SEQ ID NO:
1	RPNNNTRKSI	RPNNNTRKSI	627
3	NPYNTPIFAL	NPYNTPIFAL	628
4	RAIEAQQHLL	RAIEAQQHLL	629
5	TCKSNITGLL	TCKSNITGLL	630
9	KPVVSTQLL	KPVVSTQLL	631
10	KPCVKLTPL	KPCVKLTPLC	632, 633
11	GPKVKQWPL	GPKVKQWPLT	634, 635
12	YPGIKVRQL	YPGIKVRQLC	636, 637

TABLE 2
B37

peptide #	peptide	seq. Used	SEQ ID NO:
2	TVLDVGDAYF	TVLDVGDAYF	638
6	EPPFLWMGY	EPPFLWMGYE	639, 640
7	VPVKLKPGM	VPVKLKPGMD	641, 642
8	CPKVTFDPI	CPKVTFDPIP	643, 644
9	KPVVSTQLL	KPVVSTQLL	645
10	KPCVKLTPL	KPCVKLTPLC	646, 647
11	GPKVKQWPL	GPKVKQWPLT	648, 649
12	YPGIKVRQL	YPGIKVRQLC	650, 651

TABLE 3
A2

peptide #	peptide	seq. Used	SEQ ID NO:
13	ILKEPVHGV	ILKEPVHGVY	652, 653
14	QLPEKDSWTV	QLPEKDSWTV	654
15	NLWTVYYGV	NLWTVYYGV	655
16	QMHEDVISL	QMHEDVISLW	656, 657
17	KIEELREHLL	KIEELREHLL	658
18	DMVNQMHEDV	DMVNQMHEDV	659
19	GLKKKKSVTV	GLKKKKSVTV	660
20	ELHPDKWTV	ELHPDKWTVQ	661

TABLE 4 A11			
peptide #	peptide	seq. Used	SEQ ID NO:
21	IYQEPFKNLK	IYQEPFKNLK	662
22	VTFDPIPIHY	VTFDPIPIHY	663
23	TVQCTHGIK	TVQCTHGIKP	664, 665
24	NTPIFALKKK	NTPIFALKKK	666
25	LVDFRELNK	LVDFRELNKR	667, 668
26	PGMDGPKVK	PGMDGPKVKQ	669, 670
27	GIPHPAGLKK	GIPHPAGLKK	671
28	FTTPDKKHQK	FTTPDKKHQK	672

Conclusion. Regionalized CTL epitopes can be incorporated into a range of existing vaccine strategies, *e.g.* vectored vaccines, DNA vaccines, and recombinant protein vaccines. This approach also permit the development of novel regionalized HIV vaccines and therapeutic interventions. Alternatively, such regional CTL epitopes, collectively covering virtually all regionally-transmitted strains and prevalent HLA types could be combined into a universal HIV vaccine.

EXAMPLE 3
A "WORLD CLADE" HIV VACCINE

HLA Variation in Populations. The distribution of MHC alleles varies from population to population. In general, the MHC-peptide (epitope) interaction is governed by the sequence of the peptide: each MHC has its own constraints, which can be described as a pattern, or motif, characterizing the set of peptides that can bind in the binding groove of the MHC. While the distribution of MHC in populations inhabiting different regions of the world may restrict, to some extent, the relevance of selected epitopes in different human populations, means to surmount this difficulty have been proposed. For example, identification of CTL epitopes that may be recognized in the context of more than one

MHC, such as "promiscuous" or "clustered" MHC binding regions, may permit the development of vaccines that effectively protect genetically diverse human populations. For example, if an HIV-1 peptide could be identified that would bind and be presented by A2, A1, and A20, it is likely that it would be presented in the context of MHC of approximately 25% of Zaireans (Congolese) and greater than 50% of North American Caucasians. We and others have proposed that prospectively identifying and including such "promiscuous" CTL and Th epitopes in novel HIV-1 vaccines may enhance the utility of these vaccines in a wide range of HIV-1 endemic countries (Haynes, 348 Lancet 933-937 (1996); Cease & Berzofsky, 12 Annu. Rev. Immunol. 923-989 (1994); Bona *et al.*, 126(19) Immunology Today 126-130 (1998); Brander & Walker, in *HIV Immunology Database 1995,* Korber & Meyers, eds. (Los Alamos National Laboratories, New Mexico, 1996); Berzofsky *et al.*, 88(3) J. Clin. Invest. 876-84 (1991); Ward *et al.*, in *HIV Immunology Database 1995,* Korber & Meyers, eds. (Los Alamos National Laboratories, New Mexico, 1996)).

Database of Conserved HIV-1 MHC Ligands. We have prospectively identified regions that are conserved across the maximum number of strains ("cross-clade") of MHC binding potential that are likely to be presented by MHC molecules representing the most prevalent HLA alleles ("promiscuous"), and has selected, or weighted, the selection of potential CTL epitopes for the final vaccine construct such that HLA alleles prevalent in HIV-endemic regions of the world are adequately represented.

These are highly conserved, promiscuous peptides. Eighty peptides have been synthesized, and binding studies have been intitiated for peptides representing the following alleles: A2, A11, B35, and B7. Studies of peptides representing the following alleles: A1, A3, A24, A31, A33, B12 (44), B17, B53, Cw3, and Cw4 are next in order of priority.

Research Lab Tools; EpiMatrix. EpiMatrix is a matrix-based algorithm that ranks 10 amino acid long segments, overlapping by 9 amino acids, from any protein sequence by estimated probability of binding to a selected MHC molecule. The procedure for

developing matrix motifs was published by Schafer *et al,* 16 Vaccine 1998 (1998). We have constructed matrix motifs for 32 HLA class I alleles, one murine allele (H-2 Kd) and several human class II alleles. Putative MHC ligands are selected by scoring each 10-mer frame in a protein sequence. This score, or estimated binding probability (EBP), is derived by comparing the sequence of the 10-mer to the matrix of 10 amino acid sequences known to bind to each MHC allele. Retrospective studies have demonstrated that EpiMatrix accurately predicts published MHC ligands (Jesdale *et al.,* in *Vaccines '97* (Cold Spring Harbor Press, Cold Spring Harbor, NY, 1997)).

An additional feature of EpiMatrix is that it can measure the MHC binding potential of each 10 amino acid long snapshot to a number of human HLA, and therefore can be used to identify regions of MHC binding potential clustering. Other laboratories have confirmed cross-presentation of peptides within HLA "superfamilies" (A11, A3, A31, A33 and A68) (Jesdale *et al.,* in *Vaccines '97* (Cold Spring Harbor Press, Cold Spring Harbor, NY, 1997)). Presumably, vaccines containing such "clustered" or promiscuous epitopes will have an advantage over vaccines composed of epitopes that are not "clustered. In work performed in the TB/HIV Research Lab, we have confirmed cross-MHC binding that was predicted by EpiMatrix.

Peptides Selected for Conservation Across Clades and for CTL Response. The staff of the Los Alamos National Laboratory HIV-1 Sequence Database has compiled a list of HIV-1 sequences which are believed to be representative of currently available HIV-1 sequences. Such representative lists are available for each of the HIV genes/proteins (gag, pol, gag, vpu, env, nef, vif, vpr), although the more heavily sequenced genes (particularly env) have considerably longer lists. It is from these lists that well-conserved putative ligands have been defined.

The list for each protein was analyzed independently. We used a program called Conservatrix, developed in the TB/HIV Research Laboratory, to find conserved regions. The sequence for each isolate was divided into ten amino acid-long strings that overlapped by nine. Each of these strings was compared to all of the others using a spreadsheet

program that orders the strings from those which were in many of the sequences to those which were unique (Conservatrix). These ordered lists represent the first step in the analysis. Strings that were present in "more" (>50 for env, >25 for gag, *etc.*) HIV-1 isolates were selected for the next phase of the analysis. For example, in the case of env, 478 strings were conserved in more than 50 HIV-1 isolates and were analyzed, using EpiMatrix, for MHC binding potential clustering.

The next step was to identify which of the conserved sequences were likely to be MHC ligands (and putatively, CTL epitopes). EpiMatrix yields a "score" for each of the strings it analyzes. The somewhat arbitrary score of 20% estimated binding probability (EBP) was defined as the cut-off for this step in the analysis. This cut-off is probably too high (too specific, not sensitive enough). The complete list of conserved sequences has been archived.

To continue using *env* as an example, of the 478 conserved env strings, any peptide with an EBP of greater than 20% for any of the HLA for which EpiMatrix predictions were available was defined as being a putative ligand. 206 of the 478 well conserved strings (43%) met this criterion.

The next step was to select strings that were likely to be ligands for more than one MHC type (MHC binding potential clustering). Histograms have been constructed which indicate which regions stimulate the most HLA types (*see*, TABLE 5 below).

The list of peptides to be tested has been selected from among those regions that might bind to more than 3 different MHC molecules, paying particular attention to selecting regions that bind to HLA representative of world populations and sequences that were representative of global HIV-1 isolates. A method for weighting predictions by the prevalence of HLA alleles in populations has already been developed in the laboratory. We have performed the first two steps of the peptide selection analysis for env, pol, and gag. Twenty-eight of the peptides selected in this manner are shown in TABLE 5 below, with an abbreviated listing of the strains for which they were identified. Binding studies were also performed.

Reviewing the data shown below, it is clear that we have been able to select from a number of different peptides that are conserved in a wide range of HIV-1 clades and strains. The listing of strains for which each peptide is conserved is limited by space for this application; however, it is should be apparent that there is good cross-clade coverage of different HIV-1 clades.

The following TABLE 5 provides a sample list of peptides that are conserved across HIV-1 clades (only env is shown).

protein	conserved in # of HIV-1 strains	reference strain	strains for which sequence is conserved (partial listing)	number predicted >20%	Putative ligands for these alleles
env	70	SF1703	Z321 [318] 92UG037.8 [317] TZ017 [310] L414 [55] CI211 [50] UG273A [321] DJ264A [313] DJ263A [317] DJ	3	A*6801, B*39011, B*5801
env	69	SF2	LAI [706] HXB2R [700] NL43 [698] BRVA [696] 91US005.11 [708] MN [701] QZ4589 [703] JFL [695] SIM884 [7	3	A*3302, A*6801, B*39011
env	117	U455	SF1703 [224] Z321 [219] 92RW020.5 [205] 92RW009.14 [217] TZ017 [210] D687 [105] UG275A [216] UG27	3	B*39011, B*5101, Cw*0102
env	108	U455	SF1703 [423] 92RW020.5 [400] 92UG037.8 [410] UG275A [413] UG273A [417] CI3271 [148] LBV2310 [153]	3	B*2705, B*39011, B*5801
env	50	Z321	D687 [298] K114 [164] L414 [152] P104 [145] PZ61 [143] CI211 [145] DJ264A [408] DJ263A [416] DJ258A [4	3	B*2705, B*39011, B*5801
env	95	SF2	SF2B13 [440] LAI [450] HXB2R [445] JB02 [169] NY5CG [437] NL43 [443] JRCSF [437] JRFL [436] ALA1 [43	3	B7, B*39011, B*5801
env	114	SF1703	92RW020.5 [283] 92UG037.8 [296] PZ61 [26] DJ264A [292] DJ263A [296] CI51 [29] CI451 [29] CI3301 [29] L	3	A*0301, A*1101, B*5801
env	106	US1	US2 [556] CM237X [515] 91HT652.11 [556] 92UG005 [283] 3202A12 [564] 3202A21 [560] MANC [565] CA20	3	B*39011, B*5101, B*5801
env	58	92UG021.16	B H93TH067A [749] YU2 [753] JRFL [757] JRCSF [758] ALA1 [758] FB 93BR019.10 [760] NY5CG [760] AD	3	B14, B*39011, B*5801
env	62	U455	SF1703 [595] Z321 [590] 92RW020.5 [571] 92UG037.8 [583] D687 [572] UG275A [585] V1191A [588] DJ263A	3	B*39011, B*5101, B*5801
env	98	Z321	A_GA1LBV23 [276] SF2 [547] SF2B13 [545] LAI [553] HXB2R [548] JB02 [275] NL43 [546] JRCSF [540] JRF	4	A*3101, A*3302, A*6801, B*39011
env	74	U455	SF1703 [553] 92RW020.5 [529] 92UG031.7 [547] 92UG037.8 [541] 92RW009.14 [543] P104 [277] CI211 [27	4	A*3101, A*3302, A*6801, B*39011
env	145	SF1703	92UG031.7 [119] TZ017 [120] D687 [12] UG275A [120] UG273A [120] KENYA [120] CAR4054 [120] CAR402	3	A*0201, A*0301, B*39011
env	202	U455	SF1703 [116] Z321 [116] 92RW020.5 [114] 92UG031.7 [115] TZ017 [116] D687 [8] UG275A [116] UG273A [1	5	B7, B35, B*39011, B*5101, B*5801
env	128	U455	92UG031.7 [252] 92RW009.14 [251] D687 [139] K114 [1] UG06 [4] UG275A [250] V1191A [253] DJ264A [248]	5	B7, B35, B*39011, B*5101, B*5801
env	50	LAI	HXB2R [794] GP160EN [792] NL43 [792] JRCSF [786] JRFL [785] ALA1 [787] JH32 [805] BAL1 [794] YU2 [79	3	A*0301, B*5801, Cw*0702
env	64	SF2	SF2B13 [656] LAI [666] HXB2R [661] GP160EN [658] NY5CG [655] NL43 [658] JRCSF [653] JRFL [652] ALA	3	B40, B*4403, B*5801
env	92	SF1703	Z321 [687] 92RW020.5 [668] 92UG031.7 [686] 92UG037.8 [680] D687 [569] UG275A [682] UG273A [686] V1	3	A*3101, A*3302, B*39011
env	54	SF1703	CARSAS [285] Z3 [277] I_GM4 [131] 93BR029.2 [281] F_H93BR029A [282] 92UG046.8 [283] 92UG038.1 [24	5	B8, B35, B*5101, B*5801, Cw*0102
env	134	TZ017	CARSAS [97] CAR4054 [87] AD K124A2 [86] AD UG266A2 [87] CA ZAM184 [87] GX VI525A2 [87] EA CA	3	A*0301, A*1101, A*6801
env	117	U455	UG275A [102] DJ264A [101] DJ263A [101] DJ258A [101] CAR4054 [102] CAR423A [103] LAI [103] HXB2R [1	4	A*0201, A*0301, B*39011, B*5801
env	117	U455	SF1703 [562] Z321 [557] 92UG031.7 [556] 92UG037.8 [550] 92RW009.14 [552] CI211 [284] UG273A [556] D	6	A*0201, B7, B35, B*39011, B*5801
env	54	LAI	HXB2R [444] JB02 [168] NY5CG [436] NL43 [442] JRCSF [436] JRFL [435] ALA1 [437] JH32 [456] BAL1 [442	3	B7, B*39011, B*5801
env	94	Z321	92UG037.8 [252] TZ017 [244] UG273A [256] CARSAS [257] A_MLY10A [133] LAI [257] HXB2R [252] GP160	6	B7, B35, B*39011, B*5101, B*5801
env	53	CAR4054	FB 93BR019.10 [475] BZ126A [466] RJ103 [347] 93BR020.17 [468] 93BR029.2 [466] AR18 [208] AR18 [200	3	B40, B*4006, B*4006
env	129	U455	SF1703 [486] Z321 [481] 92RW020.5 [462] 92UG031.7 [480] 92RW009.14 [476] P104 [210] PZ61 [211] UG0	3	B40, B*4006, B*4006
env	53	92RW009.14	BF_RJ01.5 [162] CD_DI2ACD [262] CAR4081 [265] U_BUI1008A [262] RU570 [226] 93TH966.8 [264] E_92	3	A*0301, A*3101, B*39011
env	55	DJ264A	DJ263A [264] B H93TH067A [257] CB6 [141] CB7 [165] CB9 [141] US2 [265] 24612 [237] 26807 [253] 4995	3	A*0301, A*3101, B*39011
env	66	92UG037.8	92RW009.14 [410] DA_MAL [415] CA_ZAM184 [397] BF_RJ01.5 [306] FB_AR15 [133] HIV1UG3521 [406] R	3	B8, B*39011, Cw*0102
env	157	U455	SF1703 [36] Z321 [36] 92UG031.7 [35] 92UG037.8 [34] 92RW009.14 [34] TZ017 [36] KENYA [36] CARGAN [	3	A*0301, A*1101, A*6801

For example, the env peptide KLTPLCVTLN, conserved in 145 different strains on the LANL HIV sequence database, was selected from SF1703 (a clade B strain) and was conserved in SF2, SF2B13, 92UG031.7, TZ017, D687, UG275A, UG273A, CAR4054, CAR4023, CAR423A, A_MLY10A, NY5CG, JRCSF, JRFL, JH32, BAL1,YU2 , BRVA, and more, representing several different clades. The HLA class I alleles for which the string is predicted to be a good (greater than 20%) ligand were A2, A0301, and B39.

Prior to selecting peptides for synthesis, we have analyzed the peptides for (1) representation of clade A, C, D and E strains, and (2) adequate representation of potential binding to HLA alleles that are prevalent in countries where clades A, C, D, and E are transmitted. Results from assays performed in the lab to date have shown that a very high

proportion of the peptides we selected for our studies bound to T2 cells expressing the appropriate MHC *in vitro*.

TABLE 6
A^0101 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	A^0101	SEQ ID. NO:
env	107	SFEPIPIHYC	U455	207	30.25%	30
env	55	ELDKWASLWN	US1	665	2.91%	31
env	114	CTRPNNNTRK	SF1703	302	1.31%	332
env	61	GVAPTKAKRR	Z321	495	0.89%	33
env	126	SFNCGGEFFY	U455	373	0.83%	34
env	102	ITLPCRIKQI	92UG037.8	406	0.73%	35
env	93	SSNITGLLLT	AD_K124A2	448	0.70%	36
gag	57	RLRPGGKKKY	BNG	20	11.73%	37
gag	51	AISPRTLNAW	BZ126B	144	2.23%	38
gag	32	AWEKIRLRPG	BZ126B	15	2.16%	39
gag	53	FRDYVDRFYK	TN243	293	2.03%	40
pol	40	LKEPVHGVYY	IBNG	465	29.32%	41
pol	44	ETVPVKLKPG	IBNG	161	12.68%	42
pol	39	ETPGIRYQYN	IBNG	293	9.40%	43
pol	46	QKEPPFLWMG	U455	376	8.33%	44
pol	39	NNETPGIRYQ	IBNG	291	3.29%	45
pol	46	TPDKKHQKEP	U455	370	3.19%	46
pol	38	IPHPAGLKKK	IBNG	249	2.61%	47
pol	43	LVDFRELNKR	U455	228	2.23%	48
rev	13	SAEPVPLQLP	SF2	67	22.60%	49
tat	7	RGDPTGPKE$	TH475A	78	30.49%	50
vif	17	LADQLIHLYY	IBNG	102	43.60%	51
vif	10	QVDPGLADQL	SF2	97	8.75%	52
vpr	7	LHSLGQHIYE	D31	39	0.60%	53
vpu	35	RAEDSGNESE	CM240X	49	1.38%	54

TABLE 7
A^0201 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	A^0201	SEQ ID. NO:
env	91	NLWVTVYYGV	Z321	32	82.51%	55
env	110	GIKQLQARVL	U455	565	72.16%	56
env	91	QLQARVLAVE	U455	568	63.81%	57
env	145	KLTPLCVTLN	SF1703	120	50.93%	58
env	67	NMWQEVGKAM	CA16	147	49.55%	59
env	117	QMHEDIISLW	U455	101	47.82%	60
env	154	DMRDNWRSEL	CA20	193	44.72%	61
gag	31	SLYNTVATLY	UG268	77	76.09%	62
gag	25	ELRSLYNTVA	U455	74	69.48%	63
gag	88	EMMTACQGVG	U455	341	63.81%	64
gag	58	DLNTMLNTVG	BZ126B	181	63.81%	65
pol	30	LLWKGEGAVV	U455	955	99.50%	66
pol	40	ILKEPVHGVY	IBNG	464	96.43%	67
pol	27	KLLWKGEGAV	U455	954	88.23%	68
pol	28	HLKTAVQMAV	U455	885	80.90%	69
pol	39	GLKKKKSVTV	U455	253	74.16%	70
pol	48	ELHPDKWTVQ	U455	387	70.39%	71
pol	31	KIEELRQHLL	SF2	356	69.18%	72
pol	33	KLLRGTKALT	SF2	436	61.17%	73
rev	8	QILVESPTVL	LAI	101	67.94%	74
tat	7	FLNKGLGISY	UG275A	38	10.68%	75
vif	10	DLADQLIHLY	IBNG	101	54.04%	76
vif	12	HIPLGDARLV	IBNG	56	46.44%	77
vpr	9	LLEELKNEAV	LAI	22	87.89%	78
vpu	7	ILAIVVWTIV	U455	17	89.70%	79

TABLE 8
A^0301 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start		SEQ ID NO:
env	129	HSFNCGGEFF	U455	372	60.47%	80
env	138	TLFCASDAKA	U455	49	58.33%	81
env	86	HSFNCRGEFF	D687	259	55.44%	82
env	174	SLWDQSLKPC	U455	108	49.09%	83
env	157	TVYYGVPVWK	U455	35	48.61%	84
env	93	VSFEPIPIHY	U455	206	48.61%	85
env	114	CTRPNNNTRK	SF1703	302	43.25%	86
gag	31	SLYNTVATLY	UG268	77	49.34%	87
gag	31	LARNCRAPRK	BZ126B	399	32.34%	88
gag	57	RLRPGGKKKY	BNG	20	32.12%	89
gag	73	ILDIRQGPKE	U455	278	29.11%	90
pol	43	LVDFRELNKR	U455	228	52.52%	91
pol	27	QLDCTHLEGK	U455	776	50.32%	92
pol	27	AVFIHNFKRK	U455	893	43.98%	93
pol	38	QIIEQLIKKE	SF2	675	43.01%	94
pol	40	GIPHPAGLKK	IBNG	248	41.81%	95
pol	39	KVYLAWVPAH	SF2	685	36.86%	96
pol	35	AIFQSSMTKI	SF2	313	34.57%	97
pol	46	KLVDFRELNK	U455	227	33.45%	98
rev	6	KILYQSNPYP	UG273A	20	23.70%	99
tat	7	TACNNCYCKK	SF2	20	62.35%	100
vif	6	ALTALITPKK	MN	149	37.32%	101
vif	31	KLTEDRWNKP	U455	168	35.02%	102
vpr	27	WTLELLEELK	IBNG	18	22.76%	103
vpu	9	RLIDRIRERA	SC	42	37.32%	104

TABLE 9
A^1101 PEPTIDE SEQUENCES

protein	conserv-ation	sequence	ref. strain	ref. start		SEQ ID NO:
env	101	TVQCTHGIKP	U455	242	52.33%	105
env	51	FAILKCNDKK	BF_RJI01.5	121	45.11%	106
env	134	NVTENFNMWK	TZ017	87	38.39%	107
env	62	TITLPCRIKQ	92UG037.8	405	38.05%	108
env	157	TVYYGVPVWK	U455	35	33.47%	109
env	114	CTRPNNNTRK	SF1703	302	33.05%	110
env	135	VTENFNMWKN	TZ017	88	32.62%	111
gag	57	IRLRPGGKKK	BNG	19	57.42%	112
gag	64	KIRLRPGGKK	BZ126B	18	47.32%	113
gag	91	LVQNANPDCK	U455	318	33.37%	114
gag	43	ARNCRAPRKK	BZ126B	400	25.16%	115
pol	38	FTTPDKKHQK	IBNG	369	64.26%	116
pol	40	GIPHPAGLKK	IBNG	248	63.28%	117
pol	43	TTPDKKHQKE	IBNG	370	62.39%	118
pol	38	IPHPAGLKKK	IBNG	249	58.91%	119
pol	27	AVFIHNFKRK	U455	893	57.99%	120
pol	40	NTPVFAIKKK	U455	211	57.88%	121
pol	45	PGMDGPKVKQ	IBNG	169	57.65%	122
pol	27	QVRDQAEHLK	IBNG	879	55.58%	123
rev	9	PTVLESGTKE	LAI	107	31.68%	124
tat	7	TACNNCYCKK	SF2	20	70.97%	125
vif	6	IKPPLPSVKK	MN	159	51.98%	126
vif	6	ALTALITPKK	MN	149	44.77%	127
vpr	27	WTLELLEELK	IBNG	18	21.41%	128
vpu	8	WTIVFIEYRK	CDC42	23	31.58%	129

TABLE 10
A^2401PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	A^2401	SEQ ID NO:
env	67	RYLKDQQLLG	SF1703	590	58.82%	130
env	58	SYHRLRDLLL	DA_MAL	770	0.18%	131
pol	38	IYQEPFKNLK	U455	495	15.49%	132
pol	27	VYYDPSKDLI	LAI	484	0.01%	133
vif	17	YYFDCFSESA	JRCSF	110	0.02%	134
vpr	18	PYNEWTLELL	SF2	14	0.01%	135

TABLE 11
A^3101 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	A^3101 (10-mers)	SEQ ID NO:
env	92	MIVGGLIGLR	SF1703	692	71.89%	136
env	53	SLAEEEIIIR	92RW009.14	263	71.89%	137
env	98	IVQQQNNLLR	Z321	548	39.79%	138
env	74	IVQQQSNLLR	U455	541	39.79%	139
env	55	SLAEEEVVIR	DJ264A	260	39.79%	140
env	101	STVQCTHGIR	SF1703	249	13.63%	141
env	83	LQARVLAVER	U455	569	13.63%	142
gag	42	LVWASRELER	BNG	34	85.94%	143
gag	37	IVWASRELER	K98	34	85.94%	144
gag	89	IILGLNKIVR	U455	262	71.89%	145
gag	44	QMVHQAISPR	BZ126B	139	71.89%	146
pol	27	KIQNFRVYYR	U455	933	99.88%	147
pol	43	LVDFRELNKR	U455	228	39.79%	148
pol	46	KLVDFRELNK	U455	227	18.66%	149
pol	40	SMTKILEPFR	U455	317	13.63%	150
pol	29	SINNETPGIR	SF2	289	13.63%	151
pol	26	GIGGYSAGER	U455	904	13.63%	152
pol	39	TFYVDGAANR	U455	593	11.15%	153
pol	30	SQIIEQLIKK	SF2	674	8.24%	154
rev	34	GTRQARRNRR	SF2	33	2.65%	155
tat	10	KTACTNCYCK	HXB2R	19	7.36%	156
vif	6	AILGHIVSPR	JRCSF	123	71.89%	157
vif	33	QVMIVWQVDR	U455	6	59.46%	158
vpr	27	LQQLLFIHFR	U455	64	39.79%	159
vpu	21	KILRQRKIDR	CM240X	32	97.23%	160

TABLE 12
A^3302 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	A*3302 (10-mers)	SEQ ID NO:
env	51	EITTHSFNCR	UG23	93	76.02%	161
env	98	IVQQQNNLLR	Z321	548	23.98%	162
env	92	MIVGGLIGLR	SF1703	692	23.98%	163
env	91	ASITLTVQAR	U455	526	23.98%	164
env	82	AIAVAEGTDR	SF2B13	816	23.98%	165
env	74	IVQQQSNLLR	U455	541	23.98%	166
env	69	AVLSIVNRVR	SF2	699	23.98%	167
gag	89	IILGLNKIVR	U455	262	23.98%	168
gag	62	GVGGPGHKAR	U455	348	23.98%	169
gag	52	YVDRFYKTLR	ELI	240	23.98%	170
gag	48	YSPVSILDIR	ZAM19	157	23.98%	171
pol	27	ELKKIIGQVR	U455	871	52.05%	172
pol	43	LVDFRELNKR	U455	228	23.98%	173
pol	42	GSDLEIGQHR	U455	344	23.98%	174
pol	40	SMTKILEPFR	U455	317	23.98%	175
pol	29	SINNETPGIR	SF2	289	23.98%	176
pol	26	GIGGYSAGER	U455	904	23.98%	177
pol	45	EAELELAENR	U455	452	8.65%	178
pol	27	KIQNFRVYYR	U455	933	1.22%	179
rev	32	EGTRQARRNR	SF2	32	8.65%	180
tat	47	GISYGRKKRR	DJ263A	44	23.98%	181
vif	12	EVHIPLGDAR	IBNG	54	76.02%	182
vif	33	QVMIVWQVDR	U455	6	23.98%	183
vpr	7	HSRIGITRQR	JRCSF	78	23.98%	184
vpu	6	DSGNESEGDR	ELI	52	76.02%	185

TABLE 13
A^6801 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	A*6801 (10-mers)	SEQ ID NO:
env	61	GVAPTKAKRR	Z321	495	65.96%	186
env	69	AVLSIVNRVR	SF2	699	54.21%	187
env	98	IVQQQNNLLR	Z321	548	34.15%	188
env	74	IVQQQSNLLR	U455	541	34.15%	189
env	157	TVYYGVPVWK	U455	35	21.52%	190
env	134	NVTENFNMWK	TZ017	87	21.52%	191
env	101	STVQCTHGIR	SF1703	249	17.62%	192
gag	62	GVGGPGHKAR	U455	348	54.21%	193
gag	26	GVGGPSHKAR	VI310	351	54.21%	194
gag	42	LVWASRELER	BNG	34	45.90%	195
gag	37	IVWASRELER	K98	34	45.90%	196
pol	27	AVFIHNFKRK	U455	893	39.20%	197
pol	43	LVDFRELNKR	U455	228	34.15%	198
pol	32	LVEICTEMEK	SF2	189	31.46%	199
pol	27	QVRDQAEHLK	IBNG	879	31.46%	200
pol	42	LVKLWYQLEK	U455	576	21.52%	201
pol	38	FTTPDKKHQK	IBNG	369	6.44%	202
pol	35	DSWTVNDIQK	U455	404	5.56%	203
pol	40	NTPVFAIKKK	U455	211	3.41%	204
rev	34	GTRQARRNRR	SF2	33	7.44%	205
tat	10	KTACTNCYCK	HXB2R	19	9.51%	206
vif	12	EVHIPLGDAR	IBNG	54	65.96%	207
vif	33	QVMIVWQVDR	U455	6	54.21%	208
vpr	27	WTLELLEELK	IBNG	18	15.76%	209
vpu	6	DSGNESEGDR	ELI	52	24.23%	210

TABLE 14
B7 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	B7	SEQ ID NO:
env	128	KPVVSTQLLL	U455	250	67.23%	211
env	94	RPVVSTQLLL	Z321	253	62.56%	212
env	202	KPCVKLTPLC	U455	115	43.65%	213
env	54	RCSSNITGLL	LAI	449	32.95%	214
env	84	APTKAKRRVV	Z321	497	30.13%	215
env	117	RAIEAQQHLL	U455	550	28.51%	216
env	72	GPCKNVSTVQ	SF1703	243	25.30%	217
gag	58	TPQDLNTMLN	UG268	175	50.10%	218
gag	30	TPQDLNMMLN	AD_K124	180	49.09%	219
gag	60	GPGHKARVLA	U455	351	45.50%	220
gag	74	APRKKGCWKC	U455	401	38.60%	221
pol	32	QPDKSESELV	SF2	664	55.70%	222
pol	43	GPKVKQWPLT	U455	172	43.22%	223
pol	34	SPAIFQSSMT	SF2	311	21.23%	224
pol	44	SPIETVPVKL	U455	157	18.90%	225
pol	31	KIEELRQHLL	SF2	356	17.10%	226
pol	27	QVRDQAEHLK	IBNG	879	16.74%	227
pol	28	LVSQIIEQLI	SF2	672	11.11%	228
pol	29	IPAETGQETA	U455	803	11.04%	229
rev	23	LPPLERLTLD	SF2	75	68.27%	230
tat	8	GPKE$KKKVE	TH475A	83	14.25%	231
vif	7	KPPLPSVTKL	LAI	160	43.22%	232
vif	10	KPPLPSVKKL	U455	160	38.19%	233
vpr	11	FPRIWLHSLG	JRCSF	34	65.66%	234
vpu	6	LVILAIVALV	TZ012	4	8.00%	235

TABLE 15
B8 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	B8	SEQ ID NO:
env	54	NAKTIIVQLN	SF1703	286	36.95%	236
env	56	PTKAKRRVVQ	SF2	496	36.67%	237
env	119	LYKYKVVKIE	U455	476	32.46%	238
env	66	TLPCRIKQII	92UG037.8	407	24.36%	239
env	105	VPVWKEATTT	SF2	41	23.42%	240
env	131	VWGIKQLQAR	U455	563	21.82%	241
env	64	DAKAYDTEVH	92RW020.5	54	20.93%	242
gag	43	FNCGKEGHLA	U455	387	26.43%	243
gag	39	NAWVKVVEEK	BZ126B	151	20.49%	244
gag	47	DCKTILKALG	SF2	331	19.96%	245
gag	49	NAWVKVIEEK	BNG	150	19.32%	246
pol	39	GLKKKKSVTV	U455	253	73.44%	247
pol	43	GPKVKQWPLT	U455	172	72.05%	248
pol	46	AIKKKDSTKW	U455	216	51.14%	249
pol	46	FAIKKKDSTK	U455	215	49.32%	250
pol	36	QHRTKIEELR	SF2	352	43.87%	251
pol	27	ELKKIIGQVR	U455	871	35.67%	252
pol	38	AGLKKKKSVT	U455	252	25.94%	253
pol	26	GIKVKQLCKL	U455	427	25.33%	254
rev	7	IIKILYQSNP	UG273A	18	7.75%	255
tat	16	ESKKKVERET	SF2	86	65.88%	256
vif	9	TPKKIKPPLP	LAI	155	22.95%	257
vif	27	AGHNKVGSLQ	U455	137	22.95%	258
vpr	22	EAIIRILQQL	U455	58	19.22%	259
vpu	7	WLIDRIRERA	TZ023	41	6.13%	260

TABLE 16
B14 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	B14	SEQ ID NO:
env	68	ERYLKDQQLL	US2	582	97.12%	261
env	59	FSYHRLRDLL	92UG021.16	749	20.43%	262
env	106	EAQQHLLQLT	US1	562	9.22%	263
env	178	MRDNWRSELY	SF1703	480	0.35%	264
env	50	CRIKQIVNMW	Z321	418	0.28%	265
env	56	PTKAKRRVVQ	SF2	496	0.16%	266
env	66	TLPCRIKQII	92UG037.8	407	0.13%	267
gag	37	DRFFKTLRAE	U455	294	44.20%	268
gag	52	DRFYKTLRAE	TN243	298	36.29%	269
gag	26	ERFAVNPGLL	SF2	42	5.50%	270
gag	31	SLYNTVATLY	UG268	77	0.25%	271
pol	32	GAANRETKLG	U455	598	0.40%	272
pol	31	NRETKLGKAG	U455	601	0.08%	273
pol	45	KLVGKLNWAS	U455	413	0.03%	274
pol	30	EPFRKQNPDI	SF2	324	0.01%	275
pol	33	LTEEKIKALV	SF2	181	0.01%	276
pol	44	WTVNDIQKLV	U455	406	0.01%	277
rev	35	TRQARRNRRR	SF2	34	4.66%	278
tat	35	GRKKRRQRRR	SF2	48	2.30%	279
vif	27	DRWNKPQKTK	SF2	172	53.54%	280
vif	22	ERDWHLGQGV	IFA86	76	6.68%	281
vpr	6	QREPHNEWTL	LAI	11	1.91%	282
vpu	19	LRQRKIDRLI	LAI	33	4.71%	283

TABLE 17
B^1501 (10-mers) PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	B^1501 (10-mers)	SEQ ID NO:
env	93	DLRSLCLFSY	DJ259A	735	66.56%	284
env	101	QQHLLQLTVW	SF2	561	0.47%	285
gag	57	RLRPGGKKKY	BNG	20	36.98%	286
gag	31	SLYNTVATLY	UG268	77	2.43%	287
gag	71	DIRQGPKEPF	U455	280	0.38%	288
gag	83	RQANFLGKIW	U455	423	0.13%	289
pol	40	ILKEPVHGVY	IBNG	464	53.38%	290
pol	33	GQGQWTYQIY	SF2	488	42.73%	291
pol	28	VQMAVFIHNF	U455	890	42.73%	292
pol	44	IQKLVGKLNW	U455	411	4.02%	293
pol	38	EQLIKKEKVY	SF2	678	1.83%	294
pol	47	YQYNVLPQGW	U455	298	0.13%	295
pol	46	HQKEPPFLWM	U455	375	0.01%	296
rev	11	LLKTVRLIKF	MN	12	75.68%	297
tat	7	FLNKGLGISY	UG275A	38	17.27%	298
vif	10	DLADQLIHLY	IBNG	101	1.83%	299
vif	23	HLGQGVSIEW	IFA86	80	0.30%	300
vpr	23	ILQQLLFIHF	U455	63	28.91%	301

TABLE 18
B^2705 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	B^2705	SEQ ID NO:
env	108	CRIKQIINMW	U455	411	94.41%	302
env	50	CRIKQIVNMW	Z321	418	85.77%	303
env	82	RRVVQREKRA	SF1703	508	16.62%	304
env	88	KRRVVQREKR	SF1703	507	13.63%	305
env	103	RRVVEREKRA	U455	496	12.89%	306
env	51	IRSENLTNNA	CI3301	5	12.89%	307
env	90	KRRVVEREKR	U455	495	7.04%	308
gag	81	KRWIILGLNK	BZ126B	261	25.12%	309
gag	71	IRQGPKEPFR	U455	281	14.39%	310
gag	57	IRLRPGGKKK	BNG	19	12.19%	311
gag	43	ARNCRAPRKK	BZ126B	400	8.94%	312
pol	26	KRKGGIGGYS	U455	900	33.92%	313
pol	38	KRTQDFWEVQ	U455	236	5.76%	314
pol	30	HRTKIEELRQ	SF2	353	0.61%	315
pol	27	KQNPDIVIYQ	SF2	328	0.37%	316
pol	26	VRDQAEHLKT	IBNG	880	0.30%	317
pol	40	IRYQYNVLPQ	IBNG	297	0.13%	318
pol	29	KALTEVIPLT	SF2	442	0.11%	319
pol	37	WGFTTPDKKH	IBNG	367	0.09%	320
rev	13	GRSAEPVPLQ	SF2	65	47.75%	321
tat	9	RRAPQDSQTH	SF2	56	13.07%	322
vif	32	NRWQVMIVWQ	U455	3	10.24%	323
vif	11	ARLVITTYWG	LAI	62	8.14%	324
vpr	6	SRIGIIQQRR	SF2	79	97.28%	325
vpu	19	LRQRKIDRLI	LAI	33	0.63%	326

TABLE 19
B35 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	B35	SEQ ID NO:
env	202	KPCVKLTPLC	U455	115	94.43%	327
env	128	KPVVSTQLLL	U455	250	94.43%	328
env	94	RPVVSTQLLL	Z321	253	94.43%	329
env	100	CPKVSFEPIP	U455	203	83.30%	330
env	117	RAIEAQQHLL	U455	550	53.09%	331
env	54	NAKTIIVQLN	SF1703	286	39.25%	332
env	85	LPCRIKQIIN	SF1703	421	34.07%	333
gag	92	GPKEPFRDYV	U455	284	99.99%	334
gag	32	GPAATLEEMM	LBV2310	335	94.57%	335
gag	31	GPGATLEEMM	U455	334	94.57%	336
gag	58	TPQDLNTMLN	UG268	175	94.43%	337
pol	43	GPKVKQWPLT	U455	172	98.24%	338
pol	46	VPVKLKPGMD	IBNG	163	94.57%	339
pol	46	EPPFLWMGYE	U455	378	94.57%	340
pol	44	TPPLVKLWYQ	U455	573	94.57%	341
pol	34	SPAIFQSSMT	SF2	311	94.57%	342
pol	28	EPIVGAETFY	SF2	587	76.68%	343
pol	27	NPDIVIYQYM	SF2	330	54.09%	344
pol	45	KPGMDGPKVK	IBNG	168	53.59%	345
rev	23	LPPLERLTLD	SF2	75	89.28%	346
tat	14	GPKESKKKVE	SF170	83	82.99%	347
vif	9	TPKKIKPPLP	LAI	155	98.24%	348
vif	12	KSLVKHHMYI	SF2	22	76.68%	349
vpr	11	FPRIWLHSLG	JRCSF	34	98.24%	350
vpu	6	QPLVILAIVA	TZ023	2	9.91%	351

TABLE 20
B38 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	B38	SEQ ID NO:
env	121	IHYCAPAGFA	U455	213	55.70%	352
env	115	MHEDIISLWD	U455	102	46.23%	353
env	59	YHRLRDLLLI	LAI	773	23.31%	354
env	101	QHLLQLTVWG	SF2	562	9.57%	355
env	119	THGIKPVVST	U455	246	9.29%	356
env	97	THGIRPVVST	Z321	249	9.19%	357
env	129	VHNVWATHAC	U455	63	9.01%	358
gag	95	GHQAAMQMLK	U455	189	57.48%	359
gag	35	SHKGRPGNFL	SM145	436	38.92%	360
gag	28	LHPVHAGPIA	BZ167	216	23.66%	361
gag	45	VHQAISPRTL	SM145	140	12.44%	362
pol	34	AHTNDVKQLT	U455	514	50.97%	363
pol	46	KHQKEPPFLW	U455	374	47.58%	364
pol	36	QHRTKIEELR	SF2	352	25.26%	365
pol	28	EHLKTAVQMA	U455	884	19.21%	366
pol	31	KIEELRQHLL	SF2	356	14.26%	367
pol	32	QPDKSESELV	SF2	664	13.64%	368
pol	35	LTEEAELELA	U455	449	13.51%	369
pol	33	LTEEKIKALV	SF2	181	10.36%	370
rev	13	SAEPVPLQLP	SF2	67	13.03%	371
tat	21	KHPGSQPKTA	TH475A	12	22.79%	372
vif	18	IHLYYFDCFS	LAI	107	48.94%	373
vif	8	IHLHYFDCFS	U455	107	48.94%	374
vpr	6	PHNEWTLELL	LAI	14	17.41%	375
vpu	19	ESEGDQEELS	SF2	56	10.36%	376

TABLE 21
B^39011 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	B*39011	SEQ ID NO:
env	115	MHEDIISLWD	U455	102	58.82%	377
env	178	MRDNWRSELY	SF1703	480	56.02%	378
env	108	CRIKQIINMW	U455	411	49.57%	379
env	93	IRPVVSTQLL	Z321	252	49.57%	380
env	50	CRIKQIVNMW	Z321	418	49.57%	381
env	68	ERYLKDQQLL	US2	582	49.57%	382
env	59	YHRLRDLLLI	LAI	773	48.00%	383
gag	95	GHQAAMQMLK	U455	189	80.51%	384
gag	28	LHPVHAGPIA	BZ167	216	60.35%	385
gag	26	ERFAVNPGLL	SF2	42	60.35%	386
gag	38	SRELERFALN	SM145	38	56.02%	387
pol	34	AHTNDVKQLT	U455	514	80.51%	388
pol	46	KHQKEPPFLW	U455	374	75.73%	389
pol	28	EHLKTAVQMA	U455	884	70.38%	390
pol	36	QHRTKIEELR	SF2	352	64.99%	391
pol	33	LTEEKIKALV	SF2	181	58.82%	392
pol	27	VYYDPSKDLI	LAI	484	45.95%	393
pol	44	WTVNDIQKLV	U455	406	41.59%	394
pol	43	GGNEQVDKLV	U455	697	41.59%	395
rev	13	GRSAEPVPLQ	SF2	65	49.57%	396
tat	6	ERETETDPVH	BAL1	92	49.57%	397
vif	23	WHLGQGVSIE	IFA86	79	70.38%	398
vif	9	THPRISSEVH	MN	47	60.35%	399
vpr	27	WTLELLEELK	IBNG	18	52.41%	400
vpu	19	LRQRKIDRLI	LAI	33	56.02%	401

TABLE 22
B40 PEPTIDE SEQUENCES

protein	conservation	sequence	ref. strain	ref. start	B40	SEQ ID NO:
env	85	QEVGKAMYAP	SF2	425	60.96%	402
env	69	VELLGRRGWE	LAI	787	48.24%	403
env	64	LELDKWASLW	SF2	660	48.24%	404
env	51	GEFFYCNTSG	U455	378	44.21%	405
env	100	TEVHNVWATH	92UG037.8	60	32.15%	406
env	129	SELYKYKVVK	U455	474	21.60%	407
env	101	KEATTTLFCA	SF2	45	21.60%	408
gag	29	IEVKDTKEAL	BZ126B	92	60.96%	409
gag	58	EEAAEWDRLH	U455	203	48.24%	410
gag	51	GEIYKRWIIL	BZ126B	257	44.21%	411
gag	95	REPRGSDIAG	U455	225	35.87%	412
pol	43	WEFVNTPPLV	U455	568	60.96%	413
pol	44	AETFYVDGAA	U455	591	48.24%	414
pol	27	TELQAIHLAL	SF2	632	48.24%	415
pol	35	LEVNIVTDSQ	SF2	646	32.15%	416
pol	48	YELHPDKWTV	U455	386	27.53%	417
pol	38	NDVKQLTEAV	SF2	518	24.83%	418
pol	36	TEEAELELAE	U455	450	24.83%	419
pol	40	GDAYFSVPLD	U455	266	24.68%	420
rev	11	EELLKTVRLI	MN	10	48.24%	421
tat	31	LEPWKHPGSQ	U455	8	13.49%	422
vif	15	IEWRKKRYST	LAI	87	21.60%	423
vif	8	IEWRKRRYST	HAN	88	21.60%	424
vpr	19	YETYGDTWAG	SF2	47	35.87%	425
vpu	17	VEMGHHAPWD	LAI	68	48.24%	426

TABLE 23
B^40012 PEPTIDE SEQUENCE

protein	conservation	sequence	ref. strain	ref. start	B*40012	SEQ ID NO:
rev	11	EELLKTVRLI	MN	10	71.53%	427

TABLE 24
B^4006 (8mers) PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	B*4006 (8-mers)	SEQ ID NO:
env	53	SELYKYKVVE	CAR4054	476	65.30%	428
env	129	SELYKYKVVK	U455	474	65.30%	429
env	100	TEVHNVWATH	92UG037.8	60	23.25%	430
env	51	GEFFYCNTSG	U455	378	8.34%	431
env	106	IEAQQHLLQL	SF2	558	8.00%	432
env	73	REKRAVGIGA	SF1703	513	5.40%	433
env	96	VEQMHEDIIS	UG275A	100	5.16%	434
gag	28	RELERFAVNP	SF2	39	66.12%	435
gag	93	KEPFRDYVDR	U455	286	61.06%	436
gag	27	AEQASQEVKN	IC144	303	56.69%	437
gag	25	AEQATQEVKN	BZ126B	304	56.69%	438
pol	28	GEAMHGQVDC	U455	761	66.12%	439
pol	41	REILKEPVHG	IBNG	462	66.12%	440
pol	32	NEQVDKLVSA	SF2	700	56.69%	441
pol	28	AEHLKTAVQM	U455	883	56.69%	442
pol	33	EEKIKALVEI	SF2	183	56.69%	443
pol	35	PEKDSWTVND	U455	401	48.66%	444
pol	29	IEAEVIPAET	U455	798	30.65%	445
pol	36	RETKLGKAGY	U455	602	23.95%	446
rev	9	DEELLKTVRL	MN	9	56.69%	447
tat	18	MEPVDPRLEP	TH475A	1	5.16%	448
vif	11	SESAIRNAIL	JRCSF	116	16.97%	449
vif	32	MENRWQVMIV	U455	1	5.16%	450
vpr	13	EELKSEAVRH	NL43	24	65.30%	451
vpu	13	QEELSALVEM	SF2	61	56.69%	452

TABLE 25
B^4006 (9mers) PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	B*4006 (9-mers)	SEQ ID NO:
env	53	SELYKYKVVE	CAR4054	476	55.16%	453
env	129	SELYKYKVVK	U455	474	55.16%	454
env	85	QEVGKAMYAP	SF2	425	27.31%	455
env	64	LELDKWASLW	SF2	660	5.69%	456
env	117	FEPIPIHYCA	A_MLY10A	91	1.03%	457
env	101	KEATTTLFCA	SF2	45	1.03%	458
env	100	TEVHNVWATH	92UG037.8	60	1.03%	459
gag	48	AEWDRLHPVH	U455	206	55.16%	460
gag	79	EEKAFSPEVI	BZ126B	158	27.31%	461
gag	76	TETLLVQNAN	ZAM18	261	27.31%	462
gag	43	KETINEEAAE	TN243	202	27.31%	463
pol	27	TELQAIHLAL	SF2	632	55.16%	464
pol	44	AETFYVDGAA	U455	591	27.31%	465
pol	33	TEEKIKALVE	SF2	182	27.31%	466
pol	39	KEKVYLAWVP	SF2	683	27.31%	467
pol	43	WEFVNTPPLV	U455	568	12.60%	468
pol	36	TEEAELELAE	U455	450	9.06%	469
pol	38	TEMEKEGKIS	IBNG	194	5.69%	470
pol	44	LELAENREIL	U455	455	5.69%	471
rev	11	EELLKTVRLI	MN	10	5.69%	472
vif	22	RDWHLGQGVS	IFA86	77	2.42%	473
vif	32	MENRWQVMIV	U455	1	1.03%	474
vpr	19	YETYGDTWAG	SF2	47	27.31%	475
vpu	18	EELSALVEMG	SF2	62	5.69%	476

TABLE 26
B^4403 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	B*4403	SEQ ID NO:
env	64	LELDKWASLW	SF2	660	22.60%	477
env	67	LEITTHSFNC	SF1703	373	15.03%	478
env	229	DNWRSELYKY	CA20	196	11.08%	479
env	101	KEATTTLFCA	SF2	45	10.03%	480
env	68	GDLEITTHSF	SF1703	371	8.52%	481
env	106	IEAQQHLLQL	SF2	558	6.99%	482
env	82	QARVLAVERY	U455	570	5.31%	483
gag	51	GEIYKRWIIL	BZ126B	257	15.03%	484
gag	94	LGLNKIVRMY	U455	264	13.83%	485
gag	26	EEQNKSKKKA	SF2	106	7.87%	486
gag	49	QEVKNWMTET	BNG	308	6.99%	487
pol	46	KEPPFLWMGY	U455	377	48.34%	488
pol	39	NETPGIRYQY	IBNG	292	48.34%	489
pol	29	AETGQETAYF	U455	805	43.01%	490
pol	43	RELNKRTQDF	U455	232	43.01%	491
pol	36	RETKLGKAGY	U455	602	35.46%	492
pol	35	LEIGQHRTKI	SF2	348	26.06%	493
pol	28	EPIVGAETFY	SF2	587	12.02%	494
pol	38	TEMEKEGKIS	IBNG	194	10.03%	495
rev	11	EELLKTVRLI	MN	10	17.14%	496
tat	10	QPKTACTNCY	HXB2R	17	4.01%	497
vif	9	GDARLVITTY	LAI	60	19.96%	498
vif	7	GDAKLVITTY	SF2	60	19.96%	499
vpr	20	EDQGPQREPY	U455	6	12.02%	500
vpu	15	IAIVVWTIVF	CDC42	18	6.61%	501

TABLE 27
B^5101 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	B*5101	SEQ ID NO:
env	85	LPCRIKQIIN	SF1703	421	90.57%	502
env	100	CPKVSFEPIP	U455	203	86.77%	503
env	53	VAEGTDRVIE	SF2B13	819	78.20%	504
env	84	APTKAKRRVV	Z321	497	74.67%	505
env	58	APTRAKRRVV	U455	490	72.16%	506
env	72	GPCKNVSTVQ	SF1703	243	69.54%	507
env	56	GPCTNVSTVQ	KENYA	235	66.81%	508
gag	54	NPPIPVGEIY	BZ126B	251	83.21%	509
gag	26	NPPIPVGDIY	U455	249	83.21%	510
gag	63	NANPDCKTIL	VI415	325	69.27%	511
gag	96	SPRTLNAWVK	UG268	143	66.81%	512
pol	27	FPISPIETVP	U455	154	78.42%	513
pol	35	LPEKDSWTVN	U455	400	76.12%	514
pol	29	WASQIYAGIK	U455	420	66.53%	515
pol	27	TAVQMAVFIH	U455	888	63.70%	516
pol	43	QGWKGSPAIF	IBNG	306	63.12%	517
pol	28	SGYIEAEVIP	U455	795	63.12%	518
pol	32	QPDKSESELV	SF2	664	49.02%	519
pol	43	GPKVKQWPLT	U455	172	49.02%	520
rev	23	LPPLERLTLD	SF2	75	53.90%	521
tat	14	GPKESKKKVE	SF170	83	74.67%	522
vif	14	DPDLADQLIH	IBNG	99	94.14%	523
vif	10	DPGLADQLIH	SF2	99	94.14%	524
vpr	20	EAVRHFPRIW	LAI	29	81.01%	525
vpu	6	QPLVILAIVA	TZ023	2	72.16%	526

TABLE 28
B^5102 (9mers) PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	B*5102 (9-mers)	SEQ ID NO:
env	84	APTKAKRRVV	Z321	497	17.61%	527
env	58	APTRAKRRVV	U455	490	17.61%	528
env	85	LPCRIKQIIN	SF1703	421	17.61%	529
env	128	KPVVSTQLLL	U455	250	11.65%	530
env	94	RPVVSTQLLL	Z321	253	11.65%	531
env	72	GPCKNVSTVQ	SF1703	243	7.17%	532
env	56	GPCTNVSTVQ	KENYA	235	7.17%	533
gag	54	NPPIPVGEIY	BZ126B	251	13.33%	534
gag	26	NPPIPVGDIY	U455	249	13.33%	535
gag	63	NANPDCKTIL	VI415	325	5.91%	536
gag	28	NANPDCKSIL	U455	321	4.92%	537
pol	27	FPISPIETVP	U455	154	56.10%	538
pol	27	TAVQMAVFIH	U455	888	25.48%	539
pol	43	QGWKGSPAIF	IBNG	306	17.61%	540
pol	28	SGYIEAEVIP	U455	795	15.37%	541
pol	45	KPGMDGPKVK	IBNG	168	13.33%	542
pol	26	GGIGGFIKVR	U455	103	8.21%	543
pol	29	WASQIYAGIK	U455	420	4.92%	544
pol	45	KGIGGNEQVD	U455	694	3.33%	545
rev	23	LPPLERLTLD	SF2	75	1.44%	546
tat	14	GPKESKKKVE	SF170	83	6.01%	547
vif	9	IPLGDARLVI	LAI	57	28.77%	548
vif	8	IPLGDAKLVI	SF2	57	28.77%	549
vpr	20	EAVRHFPRIW	LAI	29	48.56%	550
vpu	6	QPLVILAIVA	TZ023	2	22.94%	551

TABLE 29
B^5801 (10mers) PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	B*5801 (10-mers)	SEQ ID NO:
env	189	VTVYYGVPVW	U455	34	72.75%	552
env	109	ITQACPKVSF	U455	199	68.83%	553
env	129	HSFNCGGEFF	U455	372	65.14%	554
env	86	HSFNCRGEFF	D687	259	65.14%	555
env	93	VSFEPIPIHY	U455	206	53.52%	556
env	102	ITLPCRIKQI	92UG037.8	406	48.46%	557
env	51	CSGKLICTTA	SF2	597	47.67%	558
gag	53	TSTLQEQIGW	K31	184	71.24%	559
gag	42	ETINEEAAEW	TN243	203	60.34%	560
gag	40	DTINEEAAEW	U455	199	60.34%	561
gag	36	PSHKGRPGNF	BZ126B	437	50.55%	562
pol	26	VSAGIRKVLF	SF2	707	68.83%	563
pol	41	WTYQIYQEPF	U455	491	68.83%	564
pol	45	STKWRKLVDF	U455	222	66.78%	565
pol	35	SSMTKILEPF	U455	316	66.78%	566
pol	47	QATWIPEWEF	U455	561	62.44%	567
pol	45	NTPPLVKLWY	U455	572	58.51%	568
pol	48	MGYELHPDKW	U455	384	54.50%	569
pol	40	ISKIGPENPY	U455	201	51.73%	570
rev	35	QARRNRRRRW	SF2	36	65.96%	571
tat	9	FTKKGLGISY	OYI	38	53.52%	572
vif	9	DARLVITTYW	LAI	61	57.54%	573
vif	7	DAKLVITTYW	SF2	61	57.54%	574
vpr	20	EAVRHFPRIW	LAI	29	53.52%	575
vpu	10	VAAIIAIVVW	SC	14	70.30%	576

TABLE 30
Cw^0102 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	Cw*0102	SEQ ID NO:
env	54	NAKTIIVQLN	SF1703	286	42.05%	577
env	66	TLPCRIKQII	92UG037.8	407	42.05%	578
env	117	CAPAGFAILK	U455	216	19.96%	579
env	91	QLQARVLAVE	U455	568	19.96%	580
env	152	LTVWGIKQLQ	U455	561	12.22%	581
env	106	EAQQHLLQLT	US1	562	12.22%	582
env	142	QLLSGIVQQQ	U455	536	12.22%	583
gag	36	IWPSHKGRPG	BZ126B	435	42.05%	584
gag	66	RAPRKKGCWK	U455	400	12.22%	585
gag	50	TLQEQIGWMT	K31	186	12.22%	586
gag	45	FLQSRPEPTA	SF2	450	12.22%	587
pol	29	KALTEVIPLT	SF2	442	42.05%	588
pol	28	NLKTGKYARM	SF2	503	12.22%	589
pol	32	GAANRETKLG	U455	598	12.22%	590
pol	47	WVPAHKGIGG	U455	689	12.22%	591
pol	32	LEPFRKQNPD	SF2	323	12.22%	592
pol	39	KEPVHGVYYD	IBNG	466	6.87%	593
pol	44	ELAENREILK	U455	456	6.87%	594
pol	43	GGNEQVDKLV	U455	697	6.87%	595
rev	9	ILVESPTVLE	LAI	102	6.87%	596
tat	6	DSQTHQASLS	SF2	61	12.22%	597
vif	11	PLPSVKKLTE	U455	162	42.05%	598
vif	25	HTGERDWHLG	IBNG	73	6.87%	599
vpr	25	QAPEDQGPQR	U455	3	6.87%	600
vpu	19	ILRQRKIDRL	CM240X	33	6.87%	601

TABLE 31
Cw^0702 PEPTIDE SEQUENCES

protein	conser-vation	sequence	ref. strain	ref. start	Cw*0702	SEQ ID NO:
env	50	KYWWNLLQYW	LAI	799	71.91%	602
env	83	LRSLCLFSYH	SF1703	765	68.10%	603
env	81	ARVLAVERYL	U455	571	59.94%	604
env	58	SYHRLRDLLL	DA_MAL	770	5.24%	605
env	146	FNCGGEFFYC	P104	105	4.95%	606
env	93	IRPVVSTQLL	Z321	252	3.38%	607
env	58	IRQGLERALL	U455	847	3.18%	608
gag	32	LRPGGKKKYR	BNG	21	99.90%	609
gag	31	LYNTVATLYC	K7	78	94.28%	610
gag	74	FSPEVIPMFS	U455	160	16.37%	611
gag	71	IRQGPKEPFR	U455	281	9.78%	612
pol	44	TPPLVKLWYQ	U455	573	74.16%	613
pol	26	KRKGGIGGYS	U455	900	70.51%	614
pol	46	IYQYMDDLYV	U455	334	46.95%	615
pol	46	EPPFLWMGYE	U455	378	37.86%	616
pol	46	TVLDVGDAYF	U455	261	27.09%	617
pol	42	QYALGIIQAQ	U455	654	25.31%	618
pol	40	LKEPVHGVYY	IBNG	465	19.97%	619
pol	34	KQGQGQWTYQ	SF2	486	17.05%	620
rev	22	LQLPPLERLT	SF2	73	2.99%	621
tat	7	LNKGLGISYG	UG275A	39	24.44%	622
vif	6	QYLALAALIK	NL43	146	17.40%	623
vif	6	QYLALAALIT	SF2	146	17.40%	624
vpr	10	LHGLGQHIYE	IBNG	39	21.14%	625
vpu	11	VWTIVFIEYR	CDC42	22	1.78%	626

The details of one or more embodiments of the invention are set forth in the accompanying description above. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the preferred methods and materials have been described. Other features, objects, and advantages of the invention will be apparent from the description and from the claims. In the specification and the appended claims, the singular forms include plural referents unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. All patents and publications cited in this specification are incorporated by reference.

The foregoing description has been presented only for the purposes of illustration and is not intended to limit the invention to the precise form disclosed, but only to the claims appended hereto.